VOLUME 29 NUMBER 6

NEW YORK MEETING, DECEMBER 3-6, 1907

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

PROCEEDINGS

DECEMBER 1907

NEXT MONTHLY MEETING, JANUARY 14, 1908

DECEMBER 1907 VOL. 29 No. 6

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

PROCEEDINGS

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
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1906-1907

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PROCEEDINGS

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 29 DECEMBER 1907 NUMBER 6

THE Annual Meeting of the Society in New York, December 3 to 6, it is hoped will be largely attended. It is the first held in the new home of the Society and everything has been done to make it an attractive and memorable occasion.

The opening session will be, as usual, Tuesday evening. Dr. F. R. Hutton, President, will discuss "The Mechanical Engineer and the Function of the Engineering Society." The address will express, to an extent, the hopes and wishes of those who have in view a wider field of usefulness in the work of the Society than it has ever known, and it is especially appropriate that it should come from one who has known so long and intimately the inner life of the Society.

Following the address of the President an informal reception will be held which will give an opportunity for renewal of old friendships and the making of new.

The report of Tellers on the Officers' Ballot will be announced at the close of this session.

The Wednesday morning session will be the usual formal business session of the meeting for the presentation of reports of Standing and Special Committees and reports of tellers of election of candidates for membership. Any new business should be brought before this meeting. Following the regular business a symposium on Gas Power has been arranged with papers by men who have made exhaustive studies in this field. If the time should be too limited for satisfactory discussion, opportunity will be given to continue it at a later session.

Through the courtesy of the Hudson Companies a trip of inspection will be made Wednesday afternoon through the mile-long tunnels of

the Pennsylvania Railroad under the Hudson River. Mr. Charles M. Jacobs, Chief Engineer of the Hudson Companies, has made special arrangements for guides to escort the members who wish to participate in this unique excursion. Details can be secured at the Society headquarters.

Wednesday evening at 8:15 o'clock, Mr. F. E. Ives, Honorary Member and Past President of the New York Camera Club, assisted by Mr. A. R. Stieglitz, author and editor of photographic works, will lecture on the art of Color Photography. The address will be illustrated by stereopticon views. Ladies are especially invited.

The morning and afternoon sessions on Thursday will be given over to the discussion of Foundry Practice, with very interesting papers covering its various branches.

The reception on Thursday evening is the only distinctly social event of the meeting and it is hoped to make it one of especial pleasure and enjoyment to members and their guests. Cards should be secured from the Secretary's office.

The closing session on Friday morning will cover papers on superheated steam, power transmission by friction driving, cylinder port velocities and industrial education.

Report of the Standing Committees of the Council

THE FINANCE COMMITTEE

The financial dealings of the Society have been larger than ever before in its history. We have conducted the sale of the property at 12 West 31st Street, receiving therefor $86 000 net, the investment of the Society in this property above the mortgage at the time of purchase, 1890 having been $27 000. This money has not yet been received into the possession of the Society as for legal reasons it has always stood in the name of The Mechanical Engineers Library Association and only recently has an order of the Court granted permission for the merger of the two associations and the turn-over of this money to the Society which originally advanced it. The increase of activities of the Society has necessarily been accomplished by increased expense, but the benefits of the membership are commensurate.

The Standardization Committee has provided the Society with a complete new set of forms for the books, thus rendering regularly to the Chairman and to the Treasurer, weekly statements of the financial condition of the Society. These statements are also open

at all times to the membership and scrutiny of these books and records is encouraged.

During the period of assuming the obligations of the building of the Engineering Societies, the trust funds of the Society were reinvested in the mortgage for the land. With the receipt of the subscriptions to the Land and Building Fund, this money has been put back again into the several funds, Life Membership, Library Development, Weeks' Legacy etc., with interest at 4 per cent, the amount of the interest on the mortgage; consequently the financial condition of the Society is now stronger than ever, notwithstanding the increased activities.

The Society is discounting all bills when allowable and thus the financial management is most economically administered. In order to continue to do this, however, the membership should be prompt in the payment of dues and should take kindly to all of the letters from the Secretary, urging such payment.

During the year it is contemplated that advertising will be taken in the Proceedings, not to meet any present expenses, but to provide for the forward work of the Society and to enable it to still further develop the departments and scope of the Proceedings.

We submit report of audit of the financial condition of the Society by the Audit Company of New York.

EDW. F. SCHNUCK,
J. WALDO SMITH,
E. D. MEIER, *Chairman*
ANSON W. BURCHARD
ARTHUR M. WAITT

Finance Committee

THE AUDIT COMPANY OF NEW YORK
43 CEDAR STREET, NEW YORK

November 14, 1907

COLONEL E. D. MEIER, CHAIRMAN FINANCE COMMITTEE, THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, 29 WEST 39TH STREET, NEW YORK.

Dear Sir:

Agreeably to your request, we have audited the books and accounts of The American Society of Mechanical Engineers for the year ended September 30, 1907.

The results of this audit are presented, attached hereto, in three Exhibits, as follows:

Exhibit *A* Balance sheet, September 30, 1907;

Exhibi *B* Income and Expense Account for the year ended September 30, 1907;

Exhibit *C* Cash Working Fund. Statement of Cash Receipts and Disbursements, October 1, 1906, to September 30, 1907, inclusive.

These Exhibits are presented in the form as desired by your Committee for publication in the annual Transactions of the Society.

We certify that the balance sheet and related income and expense account, presented herewith, are true exhibits of the accounts, and correctly set forth the financial position of The American Society of Mechanical Engineers on September 30, 1907, and its operations for the period stated.

Very truly yours,

THE AUDIT COMPANY OF NEW YORK

(Signed) E. T. PERINE, *President*
(Signed) F. C. RICHARDSON, *Secretary*

EXHIBIT A

BALANCE SHEET, SEPTEMBER 30, 1907

ASSETS

Furniture and fixtures, book value		$1 867.82	
Library, book value		13 282.07	
Finished publications, plates, badges, etc., at cash		11 556.66	
Initiation fees and dues receivable		4 345.00	
Due for publications, badges, room rents, etc		9 692.89	
Due from land fund subscriptions, new building		4 578.00	
Deferred payments and charges		1 003.57	
Cash, trust funds		23 154.49	
Cash, available for current expenses		7 137.95	
Total assets			$76 618.45

LIABILITIES

Current accounts payable		$2 899.97	
Initiation fees and dues paid in advance		307.50	
Unexpended subscriptions to land fund, new building		2 623.24	
Trust fund reserves:			
Library	$6 700.04		
Weeks' legacy	62.59		
Initiation fees	10 470.09		
Life membership	342.57	17 575.29	
Total liabilities		$23 406.00	
Surplus, September 30, 1907		53 212.45	$76 618.45

EXHIBIT B

INCOME AND EXPENSE ACCOUNT FOR THE YEAR ENDED SEPTEMBER 30, 1907

INCOME

Membership dues	$48 264.25	
Membership initiation fees	1 050.62	
Sales of publications, badges, etc	24 300.29	
Rentals	515.41	
Miscellaneous	2 331.36	
Total income		$76 461.93

EXPENSE PAYMENTS AND CHARGES:

Transactions, Volume 28, including estimated cost to complete	$8 400.20	
Office including salaries	19 059.65	
Meetings, Annual, Spring and Monthly	2 585.67	
Proceedings	11 487.98	
Membership development	2 415.31	
Membership lists and year book	2 232.35	
Library	1 499.30	
Rent and building operations	11 063.51	
Stores and sales department	12 849.81	
Miscellaneous	1 408.38	
Total expense payments and charges		$73 002.16
September 30, 1907, excess income for the fiscal year carried to surplus account		3 459.77
		$76 461.93

EXHIBIT C

Cash Working Fund—Statement of Cash Receipts and Disbursements, October 1, 1906 to September 30, 1907, Inclusive

RECEIPTS

Membership initiation fees and dues, rentals, sales of publications, badges, etc	$61 287.29	
Membership initiation fees and dues paid in advance	307.50	
Transportation, spring meeting	210.40	
Sales of furniture and fixtures	342.68	
Trust funds	10 303.69	
Land fund subscriptions	64 241.57	
Total receipts		$136 693.13
October 1, 1906, cash balance		3 711.60
		$140 404.73

DISBURSEMENTS

Operations fiscal year 1905–1906	$6 445.07	
Operations fiscal year 1906–1907	62 273.96	
Reduction of land mortgage—new building	27 000.00	
Interest on land mortgage—new building	7 818.00	
Capital expenditures	9 507.75	
Total disbursements	$113 044.78	
Increase in savings bank deposits	20 222.00	
		$133 266.78
September 30, 1907, cash on hand and on deposit		7 137.95
		$140 404.73

THE MEETINGS COMMITTEE

We beg herewith to submit report of the Meetings Committee to you for the past year, and in so doing would call attention to the fact that in former years the Society held only two meetings, the Annual and Spring meetings, with about four monthly reunions of a popular character at the official headquarters for the younger members of the Society. During the past year, however, professional meetings of the Society have been held regularly on the second Tuesday of each month from October to May, inclusive, excepting those months during which the Annual and Spring Meetings occurred. On several occasions eminent men from outside the Society were present and delivered very interesting addresses, such as those of Mr. Frederick P. Fish, President of the American Telephone and Telegraph Company on "The Ethics of Trade Secrets," and the address of Brigadier General William Crozier, Chief of Ordnance, U. S. A., on the "Ordnance Department as an Engineering Organization." Your body has now placed these monthly professional meetings on the same basis as the Annual and Spring meetings, so that the papers presented thereat will be given equal consideration for publication in the Transactions, and in this respect the Society is now in uniform practice with the other national engineering associations. This gives the needed opportunity for presentation of all papers and on a greater variety of subjects than was possible with but two meetings; and we will also be able to have the papers more adequately discussed than heretofore. This has placed an additional burden on your Committee, but it has been cheerfully assumed, and while the expenses of this Committee have been increased accordingly, it is felt that the Society and its members secure a generous return for the additional outlay.

The regular issue of the Proceedings is another activity in this line and is promoting a greater interest in the Society and making the membership at large feel closer to the work.

On the suggestion of this Committee cards have been mailed to each member inquiring his preference as to subjects to be treated in the Proceedings and the meetings. This will enable the Committee to further meet the desires of the membership, and also enable it to select authorities or those who have given particular study to any questions which it may be desirable to have investigated or to ask for particular discussion on specific subjects. Still greater interest and value in the Proceedings is planned for the coming year, the aim being to make these publications a running record of mechanical engineer-

ing progress and of such usefulness that no engineer can afford to be without them.

Respectfully submitted.

GEO. R. HENDERSON, *Chairman* A. E. FORSTALL, CHARLES WHITING BAKER, WILLIS F. HALL, L. R. POMEROY,	*Meetings Committee*

COMMITTEE ON LAND AND BUILDING FUND

The Committee hereby reports that, up to date, subscriptions have been received amounting to a total of about $71 000.

In order to complete the work we have undertaken we have yet to raise about $74 000.

Of the subscriptions so far received about $15 500 has come from members subscribing as such; the balance of $55 500 from manufacturing concerns interested in mechanical engineering.

Members to the number of 218, or about 7 per cent of the total membership, have subscribed an average of about $71 each.

The total cost to the Society, of raising this $71 000 so far subscribed has been about 0.4 of one per cent.

In view of the present situation your Committee is of the opinion that very little money can at this time be obtained from manufacturing concerns, but we are considering what may be done among the membership and the best methods of doing that which may seem possible to be done.

Among other things we purpose to publish, in an early issue of the Proceedings, a fully detailed account of what has been done, giving the names of subscribers and the amount subscribed by each.

Herewith, we give in tabular form, a general statement of what has been and what is yet to be accomplished.

Respectfully submitted,

FRED J. MILLER JAMES M. DODGE R. C. MCKINNEY	*Committee*

STATEMENT OF THE LAND FUND ACCOUNT

Fiscal Year ending October 1, 1907

Receipts

Subscriptions secured by the Committee	$64 237.76
Interest on same	488.70
Amounts advanced out of Am. Soc. M. E. current funds to be subsequently returned to the Society.	4 578.00
	$69 304.46

Disbursements

Dec. 24, 1904	For acquisition of proper y	$1 000.00	
May 22, 1905		3 500.00	
May 31, 1905		1 500.00	
July 24, 1905		1 971.11	
Jan. 15, 1906	Interest on mortgage	$4 000.00	
June 1, 1906		2 000.00	
Nov. 17, 1906		1 200.00	
Dec. 21, 1906		3 378.00	
June 29, 1907		3 240.00	21 789.11
June 30, 1906	Reduction of mortgage	$9 000.00	
Oct. 20, 1906		9 000.00	
July 11, 1907		18 000.00	36 000.00
Interest on advances			2 176.31
Furnishings			4 288.87
Occupancy bldg., moving library, etc.			2 171.06
Expenses of Committee			289.47
Balance cash on hand			2 589.64
			$69 304.46

Balance cash on hand	$2 589.64
Unpaid subscriptions	7 425.00
Amount received from M. E. L. A. applied Nov. 22 to reduction of mortgage	63 000.00
Amount yet to be raised to discharge obligation	73 599.36
	$146 614.00

Amount of mortgage Oct. 1, 1907	$144 000.00
Interest due Jan. 1, 1908	2 614.00
	$146 614.00

THE PUBLICATION COMMITTEE

Your Committee has received this year a larger number of papers than were received in any previous year of the Society's existence. Several of these papers are of special importance; the one by our Past President, Dr. F. W. Taylor, especially having attracted much attention from engineers all over the world. It has been extensively reprinted in engineering journals and has been translated into French, German and Russian.

About twice as much material has been published in our Proceedings and offered to the Publication Committee for the Transactions as was ever before considered. To meet this situation adequately and also to satisfy a long felt desire to have the work of the Society more logically presented, the Committee has arranged to have each volume of the Transactions cover the calendar year instead of the fiscal year. Formerly each volume covered the Annual Meeting of one administration and the Spring meeting of the following administration. Henceforth the work of one administration will appear in one volume. This, it is thought will assist the memory in locating papers and it has several manifest advantages.

It has been gratifying to the Committee to observe the extent to which the members have completed their files of back volumes; showing the appreciation of the Society at large of the valuable character of our Transactions.

Although the Meetings Committee receives the manuscripts and prepares them for presentation to the Society at its various meetings and for publication in the Proceedings the Society does not by that act obligate itself to publish this material in the Transactions. On the other hand it is distinctly of advantage to the Society to have another Committee pass upon this material and determine its value for permanent record.

Whereas nearly 2000 pages of material was published last year in the Proceedings only about half of that will be retained for the Transactions. This leads us to recommend that authors who are desirous of having their papers retained for the Transactions should be careful in preparing them to keep in mind brevity of statement so far as may be consistent with clearness and completeness

In coöperation with the Meetings Committee, the publication work of the Society is to be very much enhanced and attention will be given regularly to the including of symposiums or papers relating to all the principal divisions of engineering coming within the scope of this Society.

An interesting work now in hand is the publication of the Society history. This has been prepared by a special Committee consisting of Messrs. John E. Sweet, C. W. Hunt and H. H. Suplee, and will appear first as a serial in the Proceedings; one of the objects of this being to secure the benefit of suggestions and possible corrections by the membership. Afterward the history will be published in a single volume, uniform with the Transactions containing photogravures of all the Past-Presidents, Treasurers and Secretaries and of the several headquarters which the Society has occupied.

D. S. Jacobus, *Chairman* C. J. H. Woodbury Fred J. Miller Walter B. Snow H. F. J. Porter	*Publication Committee*

THE MEMBERSHIP COMMITTEE

During the past year the Membership Committee has considered twice as many applications for membership as were ever before presented to it in one year. 503 applications including 60 promotions, have been favorably reported. Many more applications were considered.

In addition to the above, there are 124 names on the ballot just closing and 199 applications pending. The present membership of the Society is the largest in its history, consisting of 16 honorary members, 2262 members, 324 associates and 732 juniors, a total of 3334. This is a significant indication of the progress of the Society.

The Council and members may be sure that the Membership Committee is most scrupulously scrutinizing the record of every applicant, and further, that no application is favorably passed that does not have references who are personally familiar with the engineering work of the applicant. We believe the Society was never so strict in this respect as now.

The members of the Committee feel that, while the labor of attending 16 protracted meetings has been great, they have been well repaid for their efforts.

Ira H. Woolson, *Chairman* Jesse M. Smith Henry D. Hibbard Charles R. Richards Francis H. Stillman	*Membership Committee*

THE STANDARDIZATION COMMITTEE

The Standardization Committee has from the beginning of its work, eighteen months ago, taken the view that its first duty was to provide that the largest portion of the Secretary's time should be devoted to what may be called advance work. The object of your Committee therefore has been to so organize the office and routine work of the Society that it would go forward largely independent of the Secretary.

With this in view every effort has been made during the past year to study critically the various functions constituting the regular work of the Society. This has been done primarily with the idea of reducing them to written instructions which, incorporated into a book of standards, should act as a guide to the employees of the Society in the performance of their several duties. A large part of the field has been covered and the work is constantly being increased.

Through this study of methods many opportunities for improvements, involving both increased efficiency and lowered cost, naturally have presented themselves. In any work such as this, it is difficult to make any broad statement as to exact gains in efficiency or reductions in cost. That there have been both in large measure is shown by the reports of the various Standing Committees.

In this work your Committee has enjoyed the broadest spirit of coöperation from the various standing committees. We are also happy to be able to say that we have had the active assistance of every one of the office staff of the Society.

The standards which have been adopted are all on file in the Society's office and are open to the inspection of members. Any suggestions which may lead to their betterment will always be gladly entertained.

Respectfully submitted,

FREDERICK W. TAYLOR, *Chairman*
FREDERICK R. HUTTON,
FRED. J. MILLER,
CALVIN W. RICE,
Standardization Committee

THE LIBRARY COMMITTEE

The Chairman of the Library Committee of The American Society of Mechanical Engineers desires to report to the Council at the present time that the property of the Library has been transferred from the house No. 12 West 31st Street to the upper floors of the Union Engineering Building without loss or injury, and that during the summer the books have been arranged in the new quarters, and the library

opened in working order in association with the libraries of the Founder Societies.

It is realized that one of the most valuable features in the joint library lies in the bound files and current issues of the various technical journals. In order to facilitate the use of these it has been arranged to maintain a current subject index of the contents of these periodicals by clipping the items of the Engineering Index as it is issued monthly, these being mounted on cards and arranged in a card index, accessible to users of the library. This card index is kept up closely to date, supplementing the published volumes of the Engineering Index so that it may be used to direct anyone to the latest articles in the technical journals of America, England, and the Continent. Articles which have appeared since the issue of the latest volume of the Engineering Index will be found in the card index in the case in the library, and in by far the greater number of instances, the references thus indexed may be found on the shelves of the library, either in the bound volumes or in the current unbound numbers.

The librarians will gladly assist in finding any articles thus indexed, or in explaining the arrangement of the Index.

The bound volumes of the Engineering Index are also on the shelves, available for reference upon request. This feature alone renders the library of especial value, both in finding the collected information upon any technical subject, or for investigating the state of any department of work, as in patent searches and the like.

In accordance with the authorization of the governing bodies of the three Founder Societies the chairmen of the three library committees hold meetings in conference for the general conduct of the library. This joint committee has adopted the following tentative rules for the conduct of its work:

That no questions shall be decided by majority votes of the three representatives of the three Societies, but that all decisions must be unanimous in order to become effective; dissent on the part of any one representative being sufficient to require a reference to the respective library committees, and ultimately, if necessary, to the governing bodies of the respective Societies, excepting as to matters regarding which the regular single representative is clothed with full powers.

That for the present all consideration of the question of a new organization for the administration of the three libraries, or of the appointment of any additional or general librarian, shall be postponed.

That the present arrangement, under which the three present Society librarians administer the three libraries, each under the supervision of her authorized Society representative, and in mutual coöperation as to matters of common interest or necessity, be continued.

That the reading room be open on all week-days, from 9 a. m. to 5. p. m. Only

members of the three Founder Societies, and others duly introduced by the Secretary or other authorized officer of one of the Societies, will be permitted access to the alcoves or other spaces inside the rail.

That for the protection and convenience of members the Secretary of each Society, will, upon application, issue to any member of his Society in good standing a personal, non-transferable card, entitling him to the use of the libraries in the alcoves of the reading room. This card must be signed by the person receiving it, and surrendered at the desk at the time of its presentation. At every visit he must identify himself by signing his name in the registry.

That non-members may, in the two outer alcoves, receive and consult books for which they call at the desk; or they may, on similar application to one of the Secretaries secure special cards admitting them to the inner alcoves under similar restrictions.

The librarians shall have no discretion in the matter of allowing any catalogued pamphlet or volume to be taken from either of the libraries for any purpose, but shall decline to permit any such loan unless authorized in writing so to do by the Chairman of the Committee or the Secretary of the Society to which the pamphlet or volume belongs. But a duplicate may be thus loaned at the discretion of the Librarian directly responsible.

W. J. JENKS, AMERICAN INSTITUTION ELECTRICAL ENGINEERS,
R. W. RAYMOND, AMERICAN INSTITUTION MINING ENGINEERS,
HENRY HARRISON SUPPLEE, THE AMERICAN SOCIETY MECHANICAL ENGINEERS.

Members are especially invited to visit the library when in New York, to use its facilities in every practicable manner, and to call upon the Secretary for cards entitling them to access to that portion of the room behind the desk and to the shelves.

AMBROSE SWASEY,
GEORGE F. SWAIN,
LEONARD WALDO,
FREDERICK M. WHYTE,
HENRY HARRISON SUPLEE,
Chairman.
Library Committee

At a recent conference of the Three Library Committees it was decided to keep the library open until nine o'clock in the evening on all week days except public holidays. Considerable expense is assumed by this action, and the continuance of the policy will depend upon the number of persons who avail themselves of the privilege thus offered of making more extensive use of the Library.

THE SOCIETY AND THE CELEBRATION OF THE BIRTHDAY OF ROBERT FULTON

At the celebration on November 14 by The American Scenic and Historic Preservative Society of the birthday of Robert Fulton

in the centennial year of the first trip of his "Clermont," this Society was represented by President F. R. Hutton, who was one of the speakers of the evening. He presented as his topic "The Significance of Fulton's Achievement from the View-point of the Mechanical Engineer" and spoke of the engineer as the confessed and frank worshipper of efficiency, which he defined and illustrated. The credit and brilliancy of Fulton's achievement as contrasted with the earlier attempts of Fitch, Rumsey and Evans in America, and with Miller, Symington, Bell and Hull of England comes from the superior efficiency of the Fulton result. Credit goes to Stephenson for the locomotive, to Morse for the line telegraph, to Marconi for the wireless system, to Edison for the light-bulb, in spite of ingenious and capable efforts of predecessors in their respective lines. The conquest of the air will be identified with some name yet unblazoned, in spite of the heroic efforts of Sarthos, Dumont, Langley, Zeppelin and others, whose solutions or results so far have not been practical nor efficient in the final sense.

In the second place, the measure of effectiveness is the result accomplished. If the launching and operation of the "Clermont" be compared to the great wave which radiated from an oceanic disturbance, the advance of that wave upon the surface of marine history can be followed in many directions. Notable among these trends of influence are the steam ferry boat, the quiet river boat, the sound vessel, the coastwise steamer, the freighter, and the ocean grey hound. To Fulton also we owe the first warship and to his successor, Mr. Chas. H. Haswell, late Honorary Member of The American Society, the first pleasure vessel or power yacht.

Finally was the lustre of Fulton's fame to be dimmed in the future by the oncoming of the turbine system undreamed of by Fulton or Watt, and by the development of the internal combustion motor for marine conditions? The speaker thought not, since the very widening of the scope of the power vessel of the future should only make the glory of him who first triumphed with it the more resplendent.

Other speakers were Mr. Edward Hageman Hall, Secretary of the celebrating body who gave a most enjoyable illustrated description of the precedent attempts to attain power propulsion and who was particularly detailed concerning the incidents of the "Clermont's" trip in August 7, 1807.

General Stewart L. Woodford, chairman of the combined Fulton-Hudson celebration in 1909 of the ter-centenary of the voyage of Hendrik Hudson up the river which now bears his name, spoke of

the scope and purpose of the commission. To form a Hendrik Hudson Park in New York on the bank of the river; the planning and erection of a water-gate to the city, at or near 114th Street; the securing of reservations at Verplancks Point opposite that already occupied at Stony Point, and the holding of appropriate anniversary exercises, religious, educational, military, naval and civic during a period of eight days in 1909. Beginning with Saturday the Hebrew population would open the week with suitable synagogue services; on Sunday the other faiths and denominations would follow, and so throughout the week. The speaker was specially eloquent in his hope and plea that the city in its greatness would rise to the spirit of the occasion, and make the celebration both unique and memorable.

The Committee of the Society on the Fulton Centennial in 1909 is Rear-Admiral George W. Melville and the President of the Society then in office.

THE TECHNOLEXICON

BERLIN, GERMANY

MR. CALVIN W. RICE, SECRETARY,
THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, NEW YORK.
Dear Sir:

The Society of German Engineers have resolved to discontinue the Technolexicon because the work has turned out to be expensive beyond all expectation, and because the cost reqisi te for its accomplishment within the allotted time exceeds the pecuniary means available for the Society for this purpose.

Please send all letters and other postal matter concerning the Technolexicon to the Verein Deutscher Ingenieure, Charlottenstrasse 43 (NW 7) Berlin, Germany.

For the furtherance so obligingly bestowed by you upon our Technolexicon undertaking, we once more beg to thank you most gratefully, and remain,

Yours very truly
THE VEREIN DEUTSCHER INGENIEURE
TH. PETERS
Director

THE PRESIDENT OF THE SOCIETY APPOINTED CHAIRMAN OF THE COMMITTEE ON EXHIBITS OF THE AMERICAN MUSEUM OF SAFETY DEVICES AND INDUSTRIAL HYGIENE

Prof. F. R. Hutton, President of the Society, has been appointed Chairman of the Committee on Exhibits of the American Museum

of Safety Devices and Industrial Hygiene. This carries with it also for the present the chairmanship of the Jury of Award of the Scientific American medal for the best safety appliance for the protection of the operative during the year.

At a recent gathering of interests, friendly to the work of the Museum, the great cross of the Legion of Honor was conferred on Colonel Carroll D. Wright, Secretary of the Department of Commerce and Labor, by a representative of the Ambassador of France. Professor Hutton was one of the speakers on this occasion, expanding the definition of the engineer to cover those responsible for the conduct of the factory as a tool of production, and claiming for the superintending engineer a measure of the privilege of caring for his less gifted brother at the bench and the machine. If Cain and Abel be taken as representatives of the leader of men on the one hand, and the group who are compelled to be led on the other hand by the better informed and better trained leaders, then in the crisis where the weaker or less gifted goes under, the nobler sentiment of the community will never let the leader deny that he is "his brother's keeper."

THE SOCIETY REPRESENTED AT THE MEETING OF THE TECHNOLOGY CLUB, SYRACUSE, N. Y.

Professor F. R. Hutton, President of the Society, visited Syracuse on Tuesday evening, November 26, to be the principal speaker at the Annual Banquet of the Technology Club of that city. This club is made up of engineers and others connected with the interests which center in Syracuse. The President's topic was "The Twentieth Century Engineer, His Work and His Training." Mr. Edwin M. Trump, member of the Council, is president of the club.

ENGINEERS' CLUB

The Inaugural Banquet, commemorative of the opening of the New Club House, will be given on Monday, December 9, 1907. Speakers: Andrew Carnegie, Dr. Samuel L. Clemens (Mark Twain), John Fritz, John Foard, W. H. Fletcher, chairman of the Club Building Committee, and T. Commerford Martin, president. One of the interesting features of the dinner will be the presentation of the engrossed certificate of honorary membership in The American Society of Mechanical Engineers to Andrew Carnegie.

PROGRAM

OPENING SESSION

Tuesday evening, December 3, 8:45 o'clock

The President's Address............Prof. F. R. Hutton, New York

THE MECHANICAL ENGINEER, AND THE FUNCTION OF THE ENGINEERING SOCIETY

A Social Reunion and informal reception will be held in the auditorium after the address, which will give an opportunity for members and guests to meet and exchange greetings. Ladies will be especially welcome.

SECOND SESSION

Wednesday morning, December 4, 9:30 o'clock

Business Meeting. Reports of the Tellers on Election of Members and Report of Standing and Special Committees. New business can be presented at this Session.

GAS POWER

THE RATIONAL UTILIZATION OF LOW GRADE FUELS IN GAS PRODUCERS..............................Mr. F. E. Junge
DUTY TEST ON GAS POWER PLANT.............Mr. J. R. Bibbins
CONTROL OF INTERNAL COMBUSTION FOR GAS ENGINES
Prof. C. E. Lucke
EVOLUTION OF THE INTERNAL COMBUSTION ENGINE
Prof. S. A. Reeve
INDUSTRIAL EDUCATION......................Mr. W. B. Russell

Buffet luncheon will be served at one o'clock.

INSPECTION TRIP

Wednesday afternoon, December 4, 2:00 o'clock

Members will be the guests of Mr. Charles M. Jacobs, Esq., Chief Engineer of the Hudson Companies, in an inspection of the tunnels under the Hudson River. Complete information will be found in the booklet to be issued at the meeting.

Wednesday evening, December 4, 8:15 o'clock

COLOR PHOTOGRAPHY

Mr. F. E. Ives, Honorary Member and Past President of the New York Camera Club, assisted by Mr. A. R. Stieglitz, author and editor of photographic works will deliver an address on Color Photography, which will be a complete account of the progress of the art to date, including the development of the Lumière process. The lecture will be illustrated by stereopticon views, with many stereoscopes arranged so that a large number can see the plates at the same time. Ladies are specially invited.

THIRD SESSION

Thursday morning, December 5, 9:30 o'clock

FOUNDRY PRACTICE

The Foundry Department and the Department of Engineering Design........................Mr. W. A. Bole
Molding Sand........................Mr. A. E. Outerbridge
Power Service in the Foundry.............Mr. A. D. Williams
Foundry for Bench Work, Mr. W. J. Keep and Mr. Emmet Dwyer
Volumetric Study of Cast Iron..............Mr. H. M. Lane

FOURTH SESSION

Thursday afternoon, December 5, 2 o'clock

FOUNDRY PRACTICE

Specifications for Iron, Coke and Method of Testing Output..............................Mr. R. Moldenke
Foundry Cupola and Iron Mixtures...........Mr. W. J. Keep
Foundry Blower Practice..................Mr. W. B. Snow
Patterns for Repetition Work..............Mr. E. H. Berry
Some Limitations of Molding Machines......Mr. E. H. Mumford

RECEPTION

Thursday evening, December 5, 9 o'clock

The reception will be held in the Engineering Societies Building at 9 o'clock. This is the distinctively social feature of the meeting and the attendance of the ladies is particularly desired. It is urged that no one shall remain away because the exigencies of travel have made evening dress inconvenient. Members must secure cards for themselves and friends to this reception.

FIFTH SESSION

Friday morning, December 6, 9:30 o'clock

THE SPECIFIC HEAT OF SUPERHEATED STEAM....Prof. C. C. Thomas
ENGINE DESIGN ADAPTED FOR THE USE OF SUPERHEATED STEAM.................................Mr. Max E. R. Toltz
POWER TRANSMISSION BY FRICTION DRIVING ....Prof. W. F. M. Goss
CYLINDER PORT VELOCITIES...................Mr. J. H. Wallace

INVITATIONS

Mr. F. H. Stillman, President the Watson Stillman Company, invites the members of the Society to visit a 300 horse power gas producer and engine which has just been completed at their works at Aldene, New Jersey. This invitation is extended during the meeting and afterward. Other interesting features of the works will be open to inspection.

The McGraw Publishing Company cordially invites the Society to inspect their new building, constructed entirely of reinforced concrete, at 239 West 39th Street. This is a remarkable building, being the first of its kind in the United States.

An invitation to the members to visit the Pennsylvania Crosstown Tunnel is extended by Mr. D. L. Hough, Member of the Society and president of the United Engineering and Contracting Company. Parties are limited to six. Those desiring to make the trip should communicate direct with Mr. Hough, 32 East 33d Street.

RAILROAD TRANSPORTATION NOTICE

Special concessions have been secured for members and guests attending the Annual Meeting in New York, December 3–6. Read carefully the following details.

The Trunk Line Association, the New England Passenger Association, except the Eastern Steamship Company, the Eastern Canadian Passenger Association and the Southeastern Passenger Association have granted the special rate of a fare and one-third for the round trip, when the regular fare is 75 cents and upwards.

a Buy your ticket at full fare for the going journey, between November 29 and December 5 inclusive. At the same time request a certificate, not a receipt. This ticket and certificate should be secured at least half an hour before the departure of the train.

b Certificates are not kept at all stations. Find out from your station agent whether he has certificates and through tickets. If not, he will tell you the nearest station where they can be obtained. Buy a local ticket to that point, and there get your certificate and through ticket.

c On arrival at the meeting, present your certificate to Mr. S. Edgar Whitaker at the Headquarters. A fee of 25 cents will be collected for each certificate validated. No certificate can be validated after December 6.

d An agent of the Trunk Line Association will validate certificates December 4, 5 and 6. No refund of fare will be made on account of failure to have certificate validated.

e One hundred certificates must be presented for validation before the plan is operative. This makes it important to ask for certificate.

f If certificate is validated, a return ticket to destination can be purchased, up to December 10, on the same route over which the purchaser came.

The Central Passenger Association offer a special concession of two cents per mile in each direction from points in their territory to Buffalo, Pittsburg, Parkersburg and other eastern gateways. From these points a fare and one third for the round trip will apply.

a Send to Mr. S. Edgar Whitaker, Office Manager, 29 West 39th Street, New York, for a *card order* to get a round trip ticket at reduced rates.

b Present the card, identifying you, to your ticket agent December 1, 2 or 3. This will enable you to buy a round trip ticket at the reduced rates, good for return until December 10.

c When ready to leave New York, present your ticket to the New York ticket agent, that he may witness your signature and stamp the ticket, then it will be good for the return journey.

The Western Passenger Association offer revised one-way fares to Chicago, Peoria and St Louis; these three places are points in the Central Passenger Association, and from these points purchase round trip tickets, in the manner outlined in the preceding paragraphs referring to the Central Passenger Association. The card orders must not be presented to ticket agents of western lines, as they will not be honored.

The Trunk Line Association includes the following territory:

All of New York east of a line running from Buffalo to Salamanca, all of Pennsylvania east of the Ohio River, all of New Jersey, Delaware and Maryland; also that portion of West Virginia and Virginia north of a line running through Huntington, Charleston, White Sulphur Springs, Charlottesville and Washington, D. C.

The Eastern Canadian Passenger Association includes:

Canadian territory east of and including Port Arthur, Sault Ste. Marie, Sarnia and Windsor, Ont.

The Southeastern Passenger Association includes:

Kentucky, all of West Virginia and Virginia south of a line running through Huntington, Charleston, White Sulphur Springs, Charlottesville and Washington, D. C., North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi and Tennessee.

The Central Passenger Association includes:

The portion of Illinois south of a line from Chicago through Peoria to Keokuk and east of the Mississippi River, the States of Indiana, and Ohio, the portion of Pennsylvania and New York north and west of the Ohio River, Salamanca and Buffalo, and that portion of Michigan between Lakes Michigan and Huron.

The Western Passenger Association includes:

North Dakota, South Dakota, Nebraska, Kansas, Colorado; east of a north and south line through Denver, Iowa, Minnesota, Wisconsin, Missouri; north of a line through Kansas, Jefferson City and St. Louis, Illinois; north of a line from Chicago through Peoria to Keokuk.

The New England Passenger Association includes:

Maine, New Hampshire, Vermont, Massachusetts, Rhode Island and Connecticut.

OBITUARY

EDWARD FRANCIS GAVAGAN

Edward Francis Gavagan was born in Boston, Massachusetts in 1878. He received his early training in engineering and electricity in the Massachusetts training ship, "Enterprise," and spent three years as assistant engineer on the American line steamer, "St. Paul." He was chief machinist of the United States Navy during the Spanish War and was for a time connected with the Edison Electric Illuminating Company of Boston. He was first assistant engineer, rope walk power plant, United States Navy Yard, Boston, and for one year served as a mechanical engineer detailed to the Philippine Islands, in the United States Civil Service. For three years he was mechanical engineer and traveling representative for the Parson Manufacturing Company, with which he was connected at the time of his death.

Mr. Gavagan was a Junior member of the Society, joining in 1906.

NEW BOOKS

THE BLACKSMITH'S GUIDE. By J. F. Sallows. *Technical Press, Brattleboro, Vt. 1907.* Cloth 12mo. $1.50

Contents by chapter headings: Machine Forging; Tool Forging; Hardening and Tempering; High Speed Steel; Case Hardening and Coloring; Brazing, General Blacksmithing; Appendix.

ENGINEERS' SOCIETY OF WESTERN PENNA. *Proceedings. Vol. 23. No. 7. October 1907.*

INSTITUTION OF ELECTRICAL ENGINEERS. *Proceedings. Vol. 129. No. 186. September 1907.*

MANCHESTER ASSOC'N OF ENGINEERS. *Transactions. 1906–7.* Cloth 8vo.

NORTH EAST COAST ENGINEERS AND SHIPBUILDERS. *Transactions. Vol. 23. 1906–7.*

DEPT. OF COMMERCE AND LABOR. Bulletin of the Bureau of Labor. *July 1907. Washington. 1907.* 408 p.

Wages and Hours of Labor. 1890–1906.
Retail Prices of Food. 1890–1906.

SAN FRANCISCO EARTHQUAKE AND FIRE OF APRIL 18, 1906. U. S. Geological Survey Report. *Their effects on Structures and Structural Materials. Bulletin No. 324. Washington, 1907.* 170 p. 104 Illus.

REPORT OF THE CONTROLLER OF THE CITY OF NEW YORK. *Vol. 2. 1905.* 4to. Half mor. 501 pp.

BUREAU OF STANDARDS. Department of Commerce and Labor. *Bulletin. Vol. 3. No. 4.* 727 p. *Washington. 1907.*

NEW EXCHANGES

CASTINGS. A Journal of Foundry Practice published monthly by *The Gardner Printing Co., Caxton Bldg., Cleveland, Ohio.* 4to. 48 pp. Issued monthly $1.00 per year.

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both as to positions and as to men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 15th of the month. The list of men available is made up entirely of members of the Society and these are on file, with the names of other good men, not members of the Society, capable of filling responsible positions, information about whom will be sent upon application.

POSITIONS AVAILABLE

080 Manager to take charge of general manufacturing end of Ohio concern; one preferred who is prepared to take an interest in the company. Familiarity with general machine design desirable.

081 Manufacturing concern desires good designer of special machinery; ingenious man with experience in machine design. Location New York State.

082 Machine shop making goods on order of milling machines, planers, etc., wishes superintendent to take charge of shop. Man of ability and experience; one preferred who can make substantial investment in securities of the company. Location Massachusetts.

MEN AVAILABLE.

154 Mechanical and electrical engineer; technical graduate, ten years' experience in power station and railroad construction.

155 Technical graduate, age 31, nine years' experience in drafting, designing and estimating, and three years in machine shop, desires change for position as assistant superintendent, superintendent or commercial position with engineering concern requiring executive ability.

156 Member; good appearance and address; technical and practical training; capable designer and constructor; experienced as district representative and salesman; desires to engage permanently as district representative or traveling salesman with responsible concern. Introduction of engineering specialties or improved processes preferred. No objection to long trips or going abroad.

157 Mechanical engineer, college graduate, 15 years' practical experience in hoisting and conveying machinery, machine tools, pumps, gas manufacturing, steam shovels, railroad work, etc. N. Y. City preferred.

158 Junior; graduate Yale, desires position. Five years experience in steam, hydraulic and ordnance engineering.

159 Junior Member; graduate Worcester Polytechnic, five years successful experience as erecting engineer, designer, engineering salesman and branch office manager with large concern manufacturing general line of heating and power machinery, desires position with good opportunity for advancement.

160 Cornell E.E. and M.M.E. Five years experience in design and purchase equipment. Familiar with the best practice installation and operation of steam, gas producer and water power plants. High voltage, building and operation of lighting and electric railway equipments; accounting and details of employing and handling employees. Age 32, married. Present salary $3500.

161 Junior member, Yale graduate, aged 32, desires position as superintendent in or near Chicago; experienced in machine shop and factory work as draftsman and assistant superintendent.

162 Draftsman, technical graduate, has specialized in steam and electric power plant work; power plant construction.

163 Electrical and mechanical engineer, aged 31, ten years experience in power plant design, construction and operation, is open for position with consulting engineer, or as superintendent or assistant with an electric railway or lighting company.

164 Cornell graduate, superintendent of forge shop, either blacksmithing, heavy hammer work or drop forging; at present in charge of shop embracing all classes of forge work from drop hammers to 10-ton steam hammer; 16 years experience, two years in charge of shop.

165 Member, aged 32, technical graduate, now employed as superintendent of dry process portland cement plant desires change; experienced in design, construction and operation of wet and dry process cement plants.

166 Mechanical engineer, manager, having disposed of interest in large foundry and machine shop desires to represent some good lines of machinery; could engage in designing or selling engines and mining machinery in any locality, New York preferred.

167 Associate member desires position as chief engineer or superintendent and designer with motor car or other manufacturing firm now taking up gasoline trucks; four years experience in this line, having held the positions of designer, chief draftsman, assistant manager, and superintendent. Can handle successfully a force of 150 men.

168 Member, aged 41, desires position as mechanical engineer or superintendent; 25 years experience along engineering lines; steam and oil engine work, hydraulic machinery, and calculating machines, machine tools, jigs and fixtures.

169 Technical engineer, 11 years experience in practical engineering and commercial lines, competent to take full charge of small or medium sized manufacturing company as general or works manager.

170 Junior member, technical graduate, five years experience in construction, designing, selling and inspection, desires to make connection with a New York concern where an opportunity is offered to work up to a responsible position.

171 Constructing engineer; graduate C. E.; member, 25 years experience in design, construction and superintendence of large factories, including installation of almost all classes of machinery. Design of reinforced concrete and steel structures, by product coke ovens, etc. One and a half millions construction past ten years.

172 Mechanical engineer with commercial and technical education and experience as machinist, draftsman, shop manager, designing and organizing shop systems, is open for engagement.

CHANGES OF ADDRESS

ABBOTT, Frederick Bancroft (1904) Columbia University, New York, N. Y., and 98 Comstock Ave., Providence, R. I.

ALSBERG, Julius (Junior, 1905) John Bogart, Cons. Engr., 16 Exchange Pl., and for mail, 56 W. 95th St., New York, N. Y.

ATKINS, Harold B. (1903) 527 W. 121st St., New York, N. Y.

AVERY, John S. (Junior. 1901) Cuyahoga Light Co., 2035 E. 3d St., Cleveland, O.

AYERS, Hobart B. (1903) H. J. Porter Locomotive Co., Pittsburg, Pa.

BAKER, Charles F. (1891), Acting Supt. Constr., Power & Sub-sta., Hudson Companies, 100 Broadway, and for mail, 575 W. 159th St., New York, N. Y.

BAKER, George Otis (1906) Mech. Engr., New England Engrg. Co., and for mail, 570 W. 183d St., New York, N. Y.

BARBOZA, Arthur S. (1906) Central R. R. of Brazil, Rio De Janeiro, Brazil, S. A.

BEALL, Frank F. (Junior, 1902) Packard Motor Car Co., Detroit, Mich.

BENDIT, Louis (Associate, 1905) Sales Mgr., Weber Gas Engine Co., 8th and Wall Sts., Kansas City, and 604 W. Maple St., Independence, Mo.

BERRY, Edgar H. (Associate, 1905) care of Mr. Edward A. Miller, 21 East 101st St., New York, N. Y.

BITTERLICH, Walter J. (Junior, 1906) Suite 3, 35 Norway St., Boston, Mass.

BRENNER, Wm. H. (1897) 210 Simpson St., Atlanta, Ga.

BREWER, Henry (1907) Mgr. Cartridge Dept., Winchester Repeating Arms Co., and for mail, 418 Orange St., New Haven, Conn.

BRIGGS, James M. (1903) 154 Nassau Street, New York, N. Y., and 101 Ascension St., Passaic, N. J.

BROWN, Hugh T. (1903) Engr., Stone & Webster Co., 84 State St., Boston, Mass., and for mail, care of Col. H. A. Brown, Columbia, Tenn.

CARSTENS, Alexander Bismarck (1906) Apartado Postal 74, Oaxaca, Mexico.

CHAMBERLAIN, Harry Maynard (1907) Middletown Silver Co., and for mail, 168 William St., Middletown, Conn.

COLE, Dwight S. (1903) care of Mrs. H. B. Chase, R. F. D. 3, Mason, Mich.

COLWELL, Augustus W. (1880) 1416 Michigan Ave., Columbus, O.

CRAIG, James (1897) Mech. Engr., 556 West 34th St., New York, and for mail, 120 Echo Ave., New Rochelle, N. Y.

CREELMAN, Frank (1894) 447 West 23d St., New York, N. Y.

DAVIS, Charles Ethan (1896) 86 Edward St., Hartford, Conn.

DELANY, Chas. H. (1907) Engr., Babcock & Wilcox, Bayonne, and for mail, 324 Union Ave., Elizabeth, N. J.

DIXON, Horace (1904; 1906) Pres., Dixon Steam System Co., Chicago, Ill., and for mail, Royal Thames Yacht Club, London, England.

DODWELL, John G. (Junior, 1907) Ch. Engr., 14th Street Store, and for mail, 42 Bank St., New York, N. Y.

EYNON, Thomas M. (1902) Pres., Genl. Mgr., Eynon-Evans Mfg. Co., 15th and Clearfield Sts., and 1426 Allegheny Ave., Philadelphia, Pa.

FALKENAU, Arthur (1886) Secy. and Treas., Reliance Steel Fdy. Co., Delawanna, N. J.
FISHER, Henry Donald (Junior, 1907) 30 Linden Ave., Lansdowne, Pa.
FORDYCE, John Rison (1899) Ch. Engr., Gulf Compress Co., Memphis, Tenn.
GARDNER, Thomas M. (1903) Prof. Elec. Engrg., State Agricultural College, Corvallis, Ore.
GARRATT, Ernest Albert (1907) Ch. Asst., Jacobs & Barringer, 78 Gracechurch St., London, England.
GORDON, Fred. W. (1880) Mech. Engr., Niles Bement Pond Co., 111 Broadway, New York, N. Y.
GORTON, J. C. (1897; 1899) 210 Olive St., Warren, O.
GRAY, John Lamont (Associate, 1904) Messrs. Baldwin & Gray, Engrs., and for mail, "Ardlamort," 9 Esplanade, Williamstown, Victoria, Australia.
GREGORY, William B. (1895; 1903) 31 Thurston Ave., Ithaca, N. Y.
HAMNER, Charles Sutherland (1901) 106 W. 103d St., New York, N. Y.
HARDING, Frank Welland (1896) Genl. Mech. Supt., The Canadian Rubber Co. of Montreal, Notre Dame St., and Papineau Ave., and 587a Hutchinson St., Montreal, Quebec, Canada.
HARKINS, Robert R. (Junior, 1904) 81 Elsinore St., Cleveland, O.
HEQUEMBOURG, Charles Guy (1904) Ch. Draftsman, New Jersey Zinc Co., 71 Broadway, New York, N. Y.
HERSHEY, Martin E. (1889) 37 Boyleston St., Jamaica Plain, Mass.
HOLEMAN, Louis A. (Junior, 1899) Mech. Engr., General Delivery, Cleveland, O.
HURLEY, Daniel (Junior, 1904) 44 W. 25th St., New York, N. Y.
JACKSON, Roscoe B. (Junior, 1904) E. R. Thomas Co., Buffalo, N. Y.
JENKINS, Matthew Comstock (1894) Hotel Savoy, New York, N. Y.
KENNEY, Lewis H. (Junior, 1904) Draftsman Dept. Steam Engrg., Navy Yard, League Island, Pa.
KING, Roy S. (Junior, 1904) 1911 N. Main St., Dayton, O.
KIRK, Robert H. (1895; 1903) Vice Pres., Fourness, Kitching & Co., Industrial Engrs., 27 William St., New York, N. Y.
KNOOP, Theo. M. (Junior, 1904) 1105 S. Franklin St., New Orleans, La.
KREBS, A. Sonnin (1901, Associate 1905) 806 Franklin St., Wilmington, Del.
LATTA, M. Nisbet (Junior, 1902) Cons. Engr., Combustion Utilities Co., 60 Wall St., New York, N. Y.
LEWIS, Wm. Y. (1902) Mgr., Erecting Dept., International Steam Pump Co., 114 Liberty St., New York, and for mail, 301 Barclay St., Murray Hill, Flushing, N. Y.
LIVINGSTON, Robert R. (1906) Cons. and Contracting Engr., U. S. Express Bldg., and for mail, 839 West End Ave., New York, N. Y.
LOPEZ, David H. (1897) 626 Piedmont Ave., Atlanta, Ga.
LOWE, Wm. Vose (1889; 1892) 3 Emerson St., Rochester, N. Y.
LYON, J. Lawrence (Junior, 1906) care Otto Gas Engine Wks., 136 Liberty St., New York, N. Y.
MAYER, Louis G. (Junior, 1902) Portland Ry., Light & Power Co., Portland, Oregon, and for mail, 2910 N. Senate St., Indianapolis, Ind.
MERZ, Robert M. (Junior, 1907) 57 Ninth Ave., Newark, N. J.
MOORE, Wm. Enoch (1903) Cons. Engr., West Penn. Rys. Co., 502 Bank for Savings Bldg., Pittsburg, and for mail, 202 Cedar Ave., Connellsville, Pa.
MOORE, W. J. P. (1885; 1888) present address unknown.

MURPHY, Frederick, E. (1897) 31 Sagamore St., Dorchester, Mass.
MYERS, Curtis Clark (Junior, 1905) 919 N. Meridian St., Indianapolis, Ind.
OLIVER, E. C. (Junior, 1902) 161 State St., Alpena, Mich.
PENNEY, Rupert L. (Junior, 1906) Testing Engr., Winchester Repeating Arms Co., and for mail, 80 Willard St., Westville Sta., New Haven, Conn.
PHILBRICK, Herbert S. (Junior, 1907) 509 Rollins St., Columbia, Mo.
POLSON, Joseph A. (Junior, 1906) Instr. Mech. Engrg., Mich. Agrl. Col., and for mail, P. O. Box 166, East Lansing, Mich.
POMEROY, Harry D. (1892; 1904) Draftman, L. C. Smith & Bros. Typewriter Co., Syracuse, and for mail, 201 Steuben St., Herkimer, N. Y.
PURINTON, Arthur James (1893) 13 Nahant St., Lynn, Mass.
RIGGS, John D. (1892; 1907) 6545 Perry Ave., Chicago, Ill.
ROSS, Charles Everett (1900) Cons. Engr., 165 Charles St., New York, N. Y.
ROYS, Lawrence (Junior, 1907) Allis-Chalmers Co., and for mail, 1716 Cedar St., Milwaukee, Mis.
RYDING, Herbert Charles (1900) The National Tube Co., Elyria, O.
SCHROEDER, Frederick Albert (Associate, 1907) Hotel Oxford, Boston, Mass.
SPEER, Chárles Henry (Associate, 1907) Carr & Speer, Cons. Engrs., 120 Liberty St., New York, N. Y.
SPURLING, O. C. (1907) Asst. Plant Engr. and Factory Engr., Western Electric Co., and for mail, 1676 W. Congress St., Chicago, Ill.
STEBBINS, Theodore (1903) Genl. Mgr., Texas, Traction Co., Juanita Bldg., Dallas, Texas.
STEVENS, Harold L. (Associate, 1904) Dist. Sales Agt., Lackawanna Steel Co., 217 Ellicott Sq., Buffalo, N. Y.
STEVENS, Robt. H. (Junior, 1903) Draftsman, Genl. Chemical Co., 25 Broad St., New York, N. Y., and for mail, 248 New York Ave., Brooklyn, N. Y.
STEWART, George W. (Junior, 1905) Hotel Watson, Los Angeles, Cal.
THOMAS, George C. (Junior, 1907) Engr. The Lunger Mfg. Co., and for mail, 143 Beach St., Bridgeport, Conn.
TYLER, Chas. C. (1897) 2d Vice Pres. and Secy., The Long Arm System Co., Lakeside Ave., and 38th St., N. E., Cleveland, O.
UPSON, Maxwell M. (1901; 1907) Secy. and Genl. Mgr., Raymond Concrete Pile Co., 140 Cedar St., New York, N. Y.
WALDRON, Frederick A. (1890; 1896) Industrial Engr., 37 Wall St., New York, N. Y.
WALSH, Thomas J. (Junior, 1906) 97 Howard Ave., Ansonia, Conn.
WATSON, George Linton (Junior, 1905) Civil Cons. Engr., 5455 Baxter Bldg., and for mail, 3249 N. 15th St., Philadelphia, Pa.
WETTENGEL, C. Albert (Junior, 1903) The Caney Zinc Co., and for mail, Box 266, Caney, Kansas.
WHITLOCK, Elliott H. (1901) Asst. to Factory Mgr., Nat'l Carbon Co., and for mail, "Open Hearth," Lake Ave., Cleveland, O.
WHITTED, Thomas B. (1900; 1903) Westinghouse Mch. Co., St. Louis, Mo.
WILCOX, U. C. (Junior, 1905) Instr. Machine Shop, Michigan Agricultural College, and for mail, P. O. Box 158, East Lansing, Mich.
WILCOX, John F. (1887) The Skyland Hosiery Co., Lynn, N. C.
YARYAN, Edward B. (Junior, 1903) 1805 Collingwood Ave., Toledo O.

THE EVOLUTION OF THE INTERNAL COMBUSTION ENGINE

The Problem of the Internal Combustion Engine Stated in the Light of Past Experience

By S. A. REEVE, NEW HAVEN, CONN.
Member of the Society

Regulation and Reliability Versus Efficiency

GENERAL CONSIDERATIONS

The question of the current or future development of the internal combustion engine does not turn centrally upon how to improve its fuel efficiency. It turns, instead, upon the problem of its proper regulation. Since both of these statements may seem surprising to many readers, it is necessary to give them some support from the past history of the art.

2 The general history of the heat-engine has not been guided, to any perceptible degree, by considerations of thermodynamic efficiency but by those of commercial efficiency; and the gas-engine, although supreme in thermodynamic efficiency, has been quite secondary in its commercial efficiency, as measured by the cost of fuel per horse power hour. Viewing all types of prime mover broadly, it has never been the most efficient one which has obtained paramount favor in the past. Indeed, it has usually been almost the opposite. The hot air engine, for instance, a type always fascinating to inventors because of its thermodynamic refinements, has never succeeded on the market, in spite of its superior fuel records. The history of the regenerator, viewing the engines which make use of it as a distinct type of prime mover, reveals the same thing. It is the steam engine,

To be presented at the New York Meeting (December 1907) of The American Society of Mechanical Engineers, and to form part of Volume 29 of the Transactions.

on the other hand, whose prime characteristics are mediocre efficiency and ability to pull hard whenever requested, which has always been far the most popular source of power. It may not save coal, but it saves everything else.

3 Yet even among the several types of steam engine it has never been the most efficient design which has succeeded most markedly. The winning considerations, in the steam engine field, are those of capacity for power in terms of space or weight, reliability and controllability or adaptability, coupled with reasonable efficiency. Of course, other things being the same, a more efficient has always been preferred to a less efficient engine; but greater efficiency has nearly always been accompanied by a difference in those other things; reliability and adaptability have not been so great; and the competition has always been reduced, in the long run, to those other considerations.

4 The history of the gas engine fairly bristles with this same fact. It is to be remembered that it is only in the more recent portion of this history that we may couple with the gas engine the idea of a power gas producer or a supply of natural or blast furnace gas. The gas engine's spurs were won long before any of these later aids appeared appreciably upon the field. During all of that preliminary period *the fuel cost per horse power from a gas engine or oil engine was higher than from any other prime mover known in the arts!*

5 A still more bristling fact in the history of the gas engine than the inefficacy of thermodynamic refinements is its opposite, namely, that those situations which best reveal the limitations of the gas engine are not those demanding a higher thermodynamic efficiency than even it can give. Neither are they those calling for a cheaper grade of fuel than it may consume. There is no evidence anywhere that cheap power is what is wanted, any more than there is that cheap men are what is wanted most. Instead, it is those situations which demand either better reliability or better controllability than the gas engine has to offer, which shut it out from consideration in competition with the steam engine. Of the hundreds of gas works existing in the United States, for instance, all of them using power and all of them able to make additional illuminating gas, or to divert "blue gas" as rich as blast furnace gas, for a gas engine drive without appreciable cost, *not a half dozen use gas engines.* They will not tolerate them on the premises. At Hundred, W. Va., is a pumping station for natural gas which daily handles millions of cubic feet of gas which is worth almost nothing, at that locality, to its owners, who also own the pumping station. Yet all the power used in the

station is developed from steam boilers and Corliss engines. Ask the reason why, and "Unreliability of gas-engines" is the answer.

6 For all of these reasons it must be accepted in the premises that future progress of the gas engine which most of us believe to be both possible and inevitable, must advance along lines leading to a greater degree of reliability, controllability and adaptability, into a better parallel with the solid preëminence of the steam engine in these features, and not necessarily or primarily along lines aimed at a greater thermodynamic or pecuniary fuel efficiency. Indeed, it seems to be already true to-day that almost any degree of efficiency is open to the designer or purchaser of a gas engine who is willing to accept its cost in other considerations; just as almost any speed of railroad or transatlantic travel is possible, in an engineering sense, if its cost be accepted.

7 But a choice in degree of reliability is not thus open as is choice in efficiency. If reliability be desired, the gas engine, as things stand now, must be abandoned for the steam engine. For these reasons it is the aim of this paper to state some considerations which affect the problem of gas engine *regulation*, *reliability* and *flexibility*, with a view to guiding the imagination along those grooves which it is felt must demark and limit the direction of future progress. For this purpose fundamental considerations are sufficient.

THE HIT OR MISS PLAN

8 In order to state the problem clearly it is necessary to refer first to that method of regulation which has now come to have an interest merely historic, although it is still applied frequently to small engines. This method is the one commonly known as the hit or miss plan, wherein the governor may choose only between admitting gas fully to the cylinder, for a given cycle, and shutting it off entirely.

9 Viewed from the standpoint of modern steam engine regulation, this method is unspeakably bad. Its common title "hit or miss," while based originally upon its mechanical method of action, applies equally well to the result attained. The regulation accomplished is distinctly "hit or miss" in quality. Chronographic measurements of the speed of good engines of this type show variations within each cycle as great as six per cent *under constant load*. Yet the average speed per minute varies often only two or three per cent between full and light load.

10 The poor result of this plan is due to four distinct factors, all but one of them lying outside of the question of governor design.

11 Of these the first in importance is the fact that for any given cycle the governor is given no chance to *grade* the power. It may choose only between turning on maximum power and zero power.

12 Secondly, the poor regulation is due to the fact that in each cycle the power needed for compressing the next charge is drawn from the fly wheel just at the end of the idle period of the cycle, when the external load, already maintained for three-quarters of a cycle without impulse from the piston, has forced the speed to drop below normal.

13 Thirdly, the poor regulation is due to the fact that the time at which the governor must declare to the gas admission valve whether the next cycle is to contain an explosion or not, *is previous to the time of development of that explosion by more than an entire revolution* of the fly-wheel.

14 It is merely as an aggravation of these three fundamental faults that the fourth enters. The small governors usually supplied with these "hit or miss" engines contain a vital defect in that, while the valve-gear permits no gradation of power, the governor insists upon grading its own action. That is to say, the ordinary non-synchronous fly-ball or pendulum governor assumes a different position for each speed of engine between a lower limit, for maximum power and minimum speed, and a higher one for zero power and maximum speed. But in the "hit or miss" type of gas engine violent fluctuation of power, from one extreme to the other, is the only thing possible. The best will be gotten out of a bad situation when the leap from one extreme to the other, from an explosion to a miss, is taken with as great decision as possible.

15 But this the ordinary gas engine governor quite fails to do. In its carefully graded action there is only one point, that where one knife edge is about to ride or miss the other, where it can accomplish any governing. But at this point it never acts with decision. It vacillates, and often is entrapped, by the arrival of the decisive instant just as it swings a little to one side, into doing what the next instant reveals to have been the wrong thing. Explosions and misses are not alternated in regularity, but are unnaturally bunched.

16 Such action would be entirely corrected by the use of a synchronous governor in place of the non-synchronous one. The former is useless for steam engine work, where gradation of power is the one thing desired. But for gas engine work, where gradation of power is the one thing impossible, it is ideal. It would throw the gas admission cam into and out of gear with decision, which is all that can be done.

MODERN PLANS OF GOVERNING

17 The next step forward in methods of governing gas engines may be passed over briefly. It consisted in allowing an impulse to be developed at each cycle, but set the governor to grading the amount of gas admitted with each charge. This plan was better than the "hit or miss," in its regulation, but gave very weak mixtures under all loads appreciably below the maximum; and as a weak mixture delays the period of inflammation the heat was apt to be developed, under lighter loads, too late in the stroke to permit the work being gotten out of it. The plan has now virtually been discarded.

18 To-day the governing of the majority of larger engines is performed in one of two ways. Either the charge is throttled during its entrance to the cylinder, the proportion of gas to air remaining normal, or else the suction valve closes at a point in the suction stroke determined by the governor, whereupon the charge must expand below atmospheric pressure as the suction stroke is completed. In either case the result is much the same. The modification of the impulse depends upon the existence within the cylinder, at the beginning of the compression stroke, of a charge of normal mixture of gas and air at a pressure more or less below atmospheric pressure.

19 This initial pressure before compression, of course, varies with the load, from atmospheric or near there at maximum load down to a fair degree of vacuum at light loads. It accomplishes an excellent gradation of the energy of each impulse to suit the load. The standard form of indicator-card which it produces is shown in Fig. 1, wherein *AA* is the normal or average load card, *BB* the maximum-load card and *CC* the card of some fractional load.

20 The objections to this plan, however, are twofold. In the first place, it still imposes upon the governing mechanism a delay of a complete revolution between the time when the governor may last decide what is to be the energy of the next impulse and the actual development of that impulse. This is far better than in the "hit or miss" system, but it is still far behind steam engine practice, to which, as a standard, gas engine practice will always find itself compared until it excels it. For in steam engines the working stroke is already under way when the governor finally decides what is to be the vigor of that stroke.

21 It is also to be noted that the multiplication of cylinders is no remedy for this defect. Each impulse is still apportioned by a governor action which took place one revolution previously.

22 Secondly, any variation of the load from the maximum

inevitably drops the degree of compression from the maximum. Now the efficiency of the cycle is directly associated with the degree of compression. In the pure Otto cycle, unmodified by throttling or cut-off during suction or by any provision for the expansion of the gases beyond their original volume at suction, the theoretic efficiency *F* varies with the compression-ratio *R* according to the formula

$$F = 1 - R^{-0.287}$$

Fig. 2 shows this relationship graphically. It is based upon an atmospheric pressure of 14.5 pounds, as are all other diagrams in this

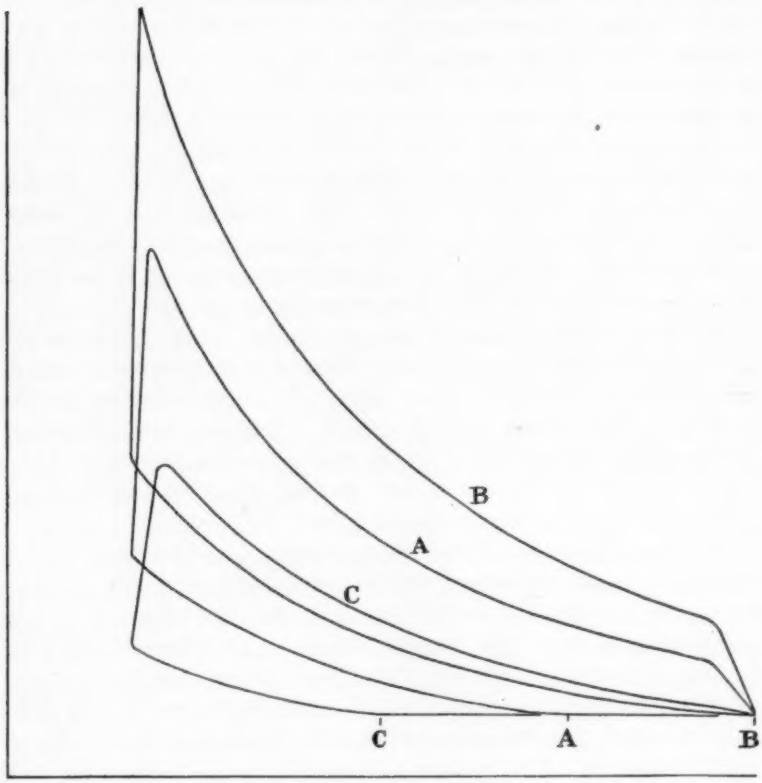

FIG. 1

article. If it be remembered that the cost of the engine is roughly proportional to the maximum pressure in the cylinder, and this again to the degree of compression, it is plain from Fig. 2 with what steadily increasing cost is obtained each decreasing increment of efficiency,

which may be sought in the standard Otto cycle by increasing the average or normal compression.

23 On the other hand, Fig. 2 also shows how the decrease in compression due to governing by the method shown in Fig. 1 may be only moderately detrimental to the efficiency, provided the lowest degree of compression amounts to some 60 pounds gage pressure. In the blast furnace gas engines this requirement may be met; but with other and more inflammable fuels the maximum degree of compression must be kept so low, in order to avoid pre-ignition, that only a moderate degree of governing reduces it below the permissible figure.

24 This second objection, however, is partially balanced by a minor gain incidental to the lighter loads, namely, the increasing degree to which the expansion of the hot gases beyond their original atmospheriç volume becomes possible as the load falls off. That is

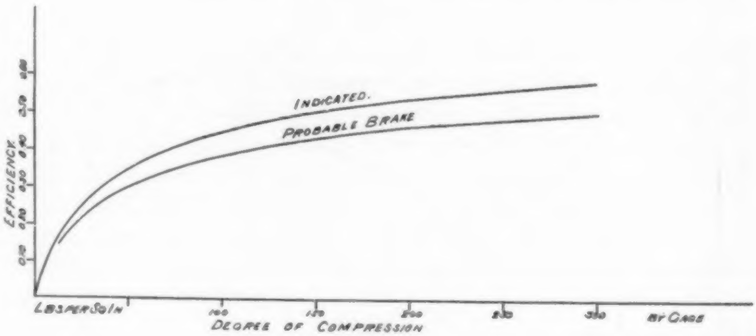

FIG. 2

to say, all work areas to the right of points A or C, in Fig. 1, represent the incidental gain, at shortened cut off, of work which is quite extra to the normal or pure Otto cycle to which Fig. 2 applies. This extra work from completed expansion becomes greater in proportion as the cut off becomes shorter, until the point is reached where the expansion line drops below atmospheric at the end of the stroke, after which it begins to decrease.

25 Fig. 3 shows the degree to which this fact is effective in keeping up the efficiency at fractional loads, in spite of the decreased compression due to the cut off on the suction stroke. In Curve T, Fig. 3, the maximum compression pressure is assumed to be 100 pounds by gage, and the explosion pressures are assumed to be three times the compression pressures. The exponent of compression and that of expansion down to the original volume is taken as 1.3; beyond that

point in the expansion it is taken as 1.1. It is further assumed that there is no scavenging and no delay in combustion. The mechanical friction is taken at 13 per cent at full load.

26 While these assumptions are too dogmatic to apply accurately to actual practice, yet they are the only ones practicable and they serve well enough to illustrate the point in mind. The result is seen to be a curve which holds up its efficiency quite well as cut offs shorten from full stroke to half stroke. Below that the efficiency drops off more rapidly.

27 Curve *A* gives a sample of actual modern engine practice of an excellent quality. On the shorter cut offs it shows the value of the delayed combustion which always accompanies short cut offs, from the greater proportion of burnt gases to fresh charge. This delayed

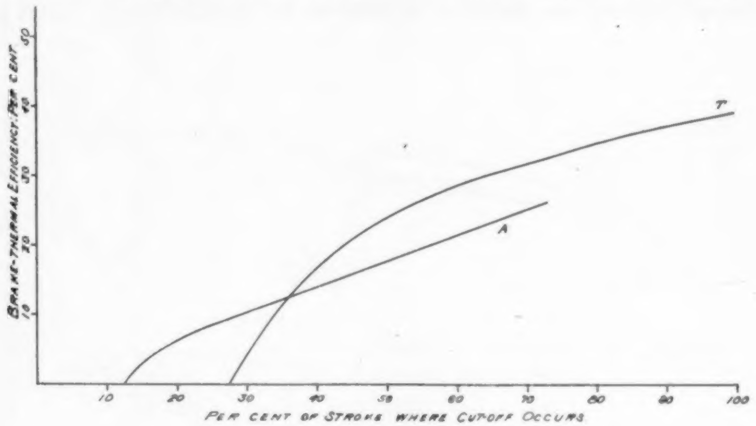

FIG. 3

combustion, which is an unquestioned source of loss at full loads, thus plays a beneficial part at the shorter cut offs which constitutes an interesting parallel with the effect of wire drawing upon steam engine efficiencies; for the wire drawing of steam, which is unquestionably harmful at the longer cut offs, becomes positively beneficial at cut offs shorter than about one-eighth stroke.

28 Had the engine of curve *A* been the best general efficiency which has been reported, instead of being only a good average the upper portion of curve *A* would have coincided closely with curve *T*.

29 But the chief lesson to be drawn from Fig. 3 yet remains to be stated. It is that the best practice yet attained with the modern gas engine leaves its efficiency curve still in a form sloping from a *maximum efficiency at maximum loads* to a lesser efficiency at all

lighter loads. In this peculiar, though fundamental, characteristic the gas engine stands alone, the writer believes, amidst the entire array of devices utilized by the power engineer. Steam engines, boilers, dynamos, gas producers, pumps, and even men, all have their point of maximum efficiency at a load considerably below their maximum possible out put. This point of maximum efficiency, or slightly above it, is understood to be the capacity at which they should be rated. Above that rating they will carry an overload ranging from 25 to 75 per cent in engines, from 20 to 200 per cent in boilers and from 50 to 100 per cent in dynamos. When subjected to this overload they are not expected to hold up the best of efficiency; but they are expected to sustain the work with operative satisfaction. At capacities below the rated load the efficiency is supposed to remain constant down to, say one-half or two-thirds of the rated capacity, below which point it may fall off rapidly without exciting censure.

30 But in the gas engine all is quite different; and this difference has had more to do with its history than has any other of its features, after the primal one of the nature of its fuel. During the greater part of that history, gas engines have been habitually rated right up to their maximum capacity. Yet every engine buyer knows that his engine's load will be at its maximum for only a small fraction of the time of operation. During the bulk of the engine's activity it must handle resistances amounting to some appreciable, although varying, fraction of the maximum.

31 This must lead to two things. In the first place, the average efficiency of the engine when engaged in actual work will be far below that shown on the maker's test plate, where the engine is carefully tested at its maximum, or rated, power. Secondly, the buyer, after having met with a sufficient number of disasters to teach him, learns to discount the maker's rating in a way which he never needs to do with other apparatus.

32 The first of these objections can be eliminated by mere honesty on the part of the maker; but the process has been a very slow one. The second objection cannot be so easily overcome. A man may build a gas engine capable of 125 horse power and be honest enough to sell it as a 100 horse power engine, which it really is. But he cannot affect the fact that the user must run his engine, under its usual load of from 80 to 100 horse power, at an efficiency far below what is actually obtainable under more favorable, but yet actual, conditions, namely, maximum load. This is the Gordian knot of gas engine regulation which no one has yet had the skill to untie, and which

the buyer usually cuts by "cutting" the gas engine and buying a steam engine.

CONCLUSIONS TO BE DRAWN AS TO THE TRUE OUTLINE OF THE PROBLEM

33 To summarize this résumé of the history of the gas engine then, the following appear to be the salient features of the premises from which its future progress must be predicted.

34 The advantages which have hitherto been cogent in its favor and the extension of which are therefore to be sought, are:

a *Not* solely in increased fuel efficiency—for with all fuels except blast furnace and producer gas, a gas engine costs more for fuel than does steam, and with either blast-furnace or producer gas its fuel is so cheap that no ordinary variation in its efficiency will appreciably affect its use;

b But chiefly in the nature of its fuel—because of the transportability, cleanliness, safety and low incidental labor-cost of gaseous or liquid fuel rather than the cheapness of the fuel itself. And of these the chief is its transportability, eliminating the need for a boiler plant. Every gas or oil engine not coupled directly to its own producer is an example of power transmission upon the most efficient plan known to man.

c Quickness of getting into action.

35 The *disadvantages* which must be eliminated are:

a *Unreliability,*—for a gas engine may, and commonly does, "lie down on its job" at any moment.

b *Lack of margin of power,*—for, when overloaded, instead of pulling slowly and inefficiently but more and more insistently, as the steam engine does, it "lies down" again.

c *Wrong characteristic,*—its average efficiency under medium load is far below its maximum efficiency.

d *Poor regulation,*—the governor's action determining any given impulse must always antedate the exertion of that impulse by one revolution of the fly-wheel.

e *Irreversibility.* Although several forms of reversing gas engines have appeared upon the market from time to time, the consensus of opinion is that the accomplishment is an unnatural one for the explosive cycle and that it has cost more, in complexity of mechanism and uncertainty of action, than it was worth.

36 It is because these features stand out boldly from the history of the gas engine, and have done so for years, that the writer has held to the following platform as defining the field of the future development of the world's heat engines, viz:

a Reliance upon liquid and gaseous fuels, rather than upon the direct use of solid fuel will steadily and rapidly increase.

b Questions of thermodynamic efficiency will hold a quite secondary place. Progress in efficiency will be made, but it will be incidental to, rather than commanding and guiding, the progress made in other lines.

c Questions of mechanical and commercial efficiency will be uppermost, and will be most active along the following lines:

1 *Reliability;*

2 *Wide margin of power over the most efficient capacity;*

3 *Regulation of each working impulse by a governor action occurring during the performance of that impulse;*

4 Reversibility;

5 General flexibility for the development, transmission and subdivision of power, at variable speeds and for divers purposes.

37 In all the above directions the steam engine sets, by example, a standard which, while plainly not perfection, is yet far ahead of existing gas engine practice. Its value has been proved by generations of experience. The gas engine of the future will not be exactly like the steam engine of today, but it will be more like that machine than it is like the gas engine of today.

THE SOLUTION OF THE PROBLEM

Modification of the Simple Otto Type Engine

THE VARIATION OF THE CLEARANCE-SPACE

38 In the above list of desiderata, item 2, if not the one of the most pressing importance, seems to be attainable with the least modification of the existing engine and its cycle. Let us imagine an engine in which the governing is done by cut off on the suction stroke, and in which the clearance space is variable in proportion with the volume of atmospheric charge taken in. The results to be expected from such an engine are shown by the indicator cards of Fig. 4 and the characteristic efficiency curves of Fig. 5. In Fig. 4 the normal

load card and its corresponding clearance space are shown by the full lines, marked *N*. The overload or maximum card and its clearance are shown by the broken and dotted lines, marked *O*. The half load card and clearance are shown by the broken lines, marked *H*.

39 In Fig. 5 the curve A_c shows the brake-efficiency of an existing engine of the better class. It is the same curve as A of Fig 3, but laid off to a new horizontal scale, viz: in terms of cut-off on the suction-

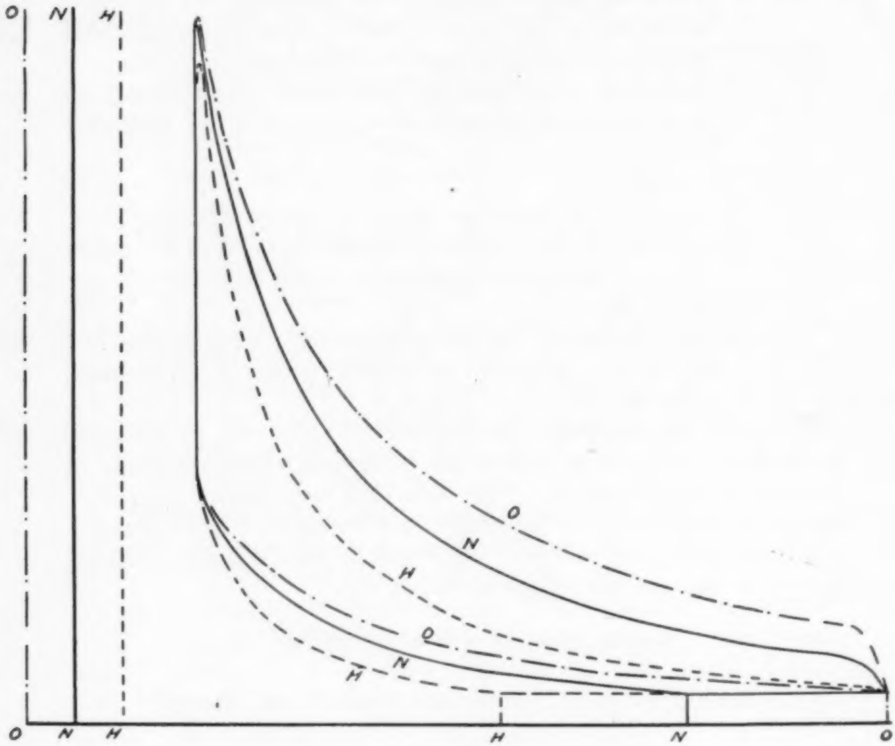

FIG. 4

stroke. Curve A_L is the same curve laid off to the horizontal scale of rated powers of Fig. 5. Curve V shows the actual brake-efficiency to be expected from our hypothetical variable-clearance engine, upon the supposition that at the same point of cut-off (m) which denotes the maximum cut-off for the existing engine it possesses the same efficiency; which assumption seems reasonable. Curve V refers to both horizontal scales simultaneously; in fact, it determines the new

power-scale of Fig. 5 which effects the distortion of curve A of Fig. 3 into Curve A_L of Fig. 5.

40 To explain, the existing engine which has been taken as a standard of comparison has its latest cut off at about 72 per cent of the suction stroke, and at that cut off develops its best brake efficiency of 26 per cent. At that cut off it exerts a power which is 17 per cent above the arbitrary rating which was assigned to it by its builders. These points are to be seen on the diagram by following up from point 72 on the scale of cut offs till the extremity of curve A_c is reached. Following horizontally to the right, this same efficiency is found to prevail in curve A_L at point 117 of the load-scale.

41 This point *m* represents the best that the existing engine can do. It may not take on a later cut-off than 72 per cent, in order to

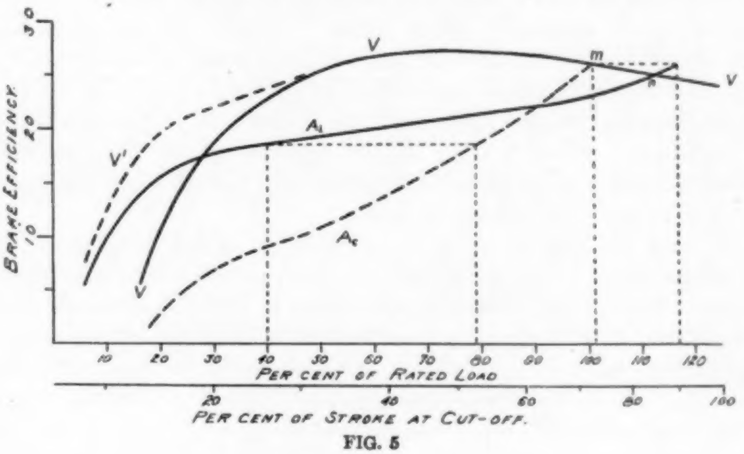

FIG. 5

expand its range of maximum power, or there will arise danger of pre-ignition from overcompression. It may not increase its rather small clearance in order to avoid this trouble, or it will reduce its compression and efficiency at all loads below point 117. It may not arbitrarily increase its power rating, in order to improve its efficiency at any stated fractional load, without losing its margin of power above its rating, which at 17 per cent is already too small. It may not arbitrarily decrease its rating, in order to enlarge its margin of power, without leading to its habitual use at loads so small as to ruin its average efficiency, while at the same time making it a very expensive engine in first cost per horse power.

42 In order to make the comparison between the existing and the hypothetical variable clearance engine as fair as possible, therefore,

it is assumed that the new engine, when cutting off at 72 per cent of stroke, has the same clearance, the same compression, the same efficiency and the same power as the existing engine; but that power, instead of being called 17 per cent above rated power, as in the existing engine, is called virtually rated power, or 100 per cent on the power scale (the diagram shows it as 101 per cent). This seems to be as fair an assumption for an unbuilt engine as one may make.

43 In the variable clearance engine there is no objection to using a later cut off, if the load calls for it; for overcompression will be avoided by the automatic increase of the clearance with the cut off as is shown by the change from diagram *N* to diagram *O* in Fig. 4. By the time that cut off has been extended to full stroke (100 per cent on the cut off scale) the efficiency will have fallen from 26 to 24 per cent and the power will have increased to 25 per cent above normal rating—a margin of power which, I believe, no gas engine has yet offered to the market, at least without some of the arbitrary penalties described above and which do not apply here. If the cut off be shortened below 72 per cent there is now no loss of compression to vitiate the efficiency. At 50 per cent cut off, for instance, the power has fallen to 55 per cent of normal and the efficiency has risen to over 27 per cent instead of falling.

44 It is the load scale, of course, which is of sole interest to the gas engine user. The cut off scale is a guide merely to the gas-engine builder. The latter, indeed, is introduced in the diagram only as a necessary means of stepping from one type of engine to the other. The existing engine has a relation of power to cut off quite different from that shown by the superposition of the two horizontal scales of the diagram, which gives, instead, the relation of power to cut off for the variable clearance engine. Thus, the existing engine develops 40 per cent of its rated load at a cut off of about 53 per cent, where it gives an efficiency of 18.5 per cent. The variable clearance engine, in order to develop 40 per cent of its rated power, must have a cut off of 25 per cent, and would then develop an efficiency of 22.7 per cent; or, if run at 53 per cent cut off, like the existing engine, it would develop 79 per cent of its rated power at an efficiency of 27 per cent.

45 It is to be remembered here that curve V is more or less academic in its character. While the influence of such phenomena as delayed combustion, etc., would not affect its form as markedly as they would the characteristic of a constant clearance engine, yet there would be a tendency to its distortion toward an increase of efficiency at the shorter cut offs. Moreover, while it may be possible to control the clearance space of an explosive engine through a

moderate range, it will develop, as the investigation proceeds, that there is no hope of adjusting it down to proportionality with the shorter cut offs. After the clearance, together with the cut off, has been reduced to a certain point, they can be reduced no further. From this point down to still smaller loads the engine must regulate as a constant clearance machine, with a curve like A_L of Fig. 5 in form, but probably higher. Curve *V* would probably be varied into some such form as V′ at the shorter cut offs.

46 The gain which has been accomplished by the variation of the clearance is evident at a glance. It lies in two directions:

47 First, the range of power has been extended. In the diagram the new engine apparently extends only to 25 per cent overload, while the existing engine goes to 17 per cent. But this is a referring the comparison to a quite arbitrary basis, namely, the builder's rating. A more correct statement would be that the new engine possesses its 25 per cent margin above its *natural* rating, or the point of maximum efficiency; whereas the old engine possesses no margin at all beyond that point. Another way of stating it is that if the new engine's builder should rate his machine at 60 per cent cut off, with an efficiency of over 27 per cent, he would get a margin of power above rating of 42 per cent; whereas if the existing engine's builder should rate it at such a point that it would possess a margin of 42 per cent overload, he must incur an efficiency at rated load of only 20 per cent, or a fifth less than his engine is really capable of doing.

48 Secondly, there is a great gain in *average* efficiency, although the efficiency at 72 per cent cut off is the same for the two engines. Assuming that an ordinary load will fluctuate evenly from 40 to 100 per cent of rated load, the old engine's efficiency averages at 20.7 per cent, whereas that of the new engine is 26.1 per cent, or a gain of over one-quarter. Should the load range similarly, from 30 to 115 per cent of the rating, the two efficiencies will be 21.1 and 25.3 per cent respectively, or a gain of one-fifth.

49 These gains are substantial ones. They are undoubtedly worth the seeking, although the obstacles in the way appear to be stupendous. To vary the clearance space, under governor control, of a cylinder subject to pressures ranging upward to 400 pounds per square inch is no easy task. Nevertheless, the situation is not without hope. Three general lines of solution are open to the adventurous designer. Two of these rely upon, as the means for varying the clearance space, either

a Mechanism, or

b Water pockets

respectively. The third is an indirect means for accomplishing the same end and will be treated later under the head of Outside Compression.

50 A *Mechanism:* This method would most naturally start, in its conception, with a movable head to the cylinder of an ordinary gas-engine, sliding as a piston in a continuation of the cylinder bore. Such a sliding head must be controlled by means capable of withstanding a total pressure of 400 pounds per square inch. Two such means are standard devices in the arts, viz: the screw, and the hydraulic cylinder.

51 As to the screw, although cumbrous in appearance, it is not out of the question. A diameter at the bottom of its threads of one-fifth the cylinder diameter would place its metal under a stress which is within the limits. For its operation there would naturally be provided a rotating nut held in thrust bearings, the nut being itself in the form of a worm wheel driven by a tangential worm. A second worm-drive applied to this main worm would probably provide that slowness and elasticity of drive which is requisite for success. For it is obvious that the clearance piston screw and nut will be bound and immovable in their bearings during the brief period of the heaviest pressures, whereas they will move with merely frictional resistance during the idle strokes of the main piston. Somewhere in the driving mechanism, therefore, must be provided an elasticity which will permit the heavy nut to stop for an instant while the driving end of the mechanism continues steadily in motion, without a break.

52 It has been computed that such a gear would be practicably slow and elastic if it should move the clearance-piston from maximum to minimum clearance, or the reverse, in two or three minutes. For any ordinary fluctuations in load this would be amply fast. All that is wanted usually is an adjustment of the clearance into correspondence with the average load of the period. For, it may be necessary to explain, the clearance-variation is not a means of regulation of engine-power and speed at all. The governor will be at work as usual. It aims merely to elevate the average efficiency and to extend the range of extreme power, by proportioning itself to the prevailing load in a general way.

53 As to the means for guiding this clearance control mechanism, the first thought might be that its connection with the governor were the proper thing, that the clearance might be proportional always to the cut off. Second thought, however, shows this plan to be full of peril. The desired result would be obtained only when the relation between the position of the governor for the moment and the resultant

position of the clearance piston were just right. The question of the relative adjustment between the two would be an unending source of trouble after the engine had once left the factory and its friends.

54 Third thought on this question returns to the original object of the entire enterprise, viz: the maintenance of compression and explosion pressures virtually constant. Let, then, a certain maximum explosion pressure be chosen, say 350 pounds. Let the cylinder be equipped with a tiny safety valve set to blow off at this pressure. Let the discharge from this safety valve be utilized to operate a piston or diafram, to throw into or out of gear a small friction clutch in the train of mechanism between main shaft and clearance screw. Plenty of power is available. Since the motion of the clearance piston is very slow and its resistance (when it will move at all) merely frictional, friction gearing ought to suffice for this job. The clearance piston will then creep slowly in or out, following the general fluctuations of load, so as to keep explosion pressures very nearly at the chosen point.

55 The above supposition is described in detail merely to illustrate the statement that the variation of the clearance is a problem embodying its solution automatically in its premises. It is the heavy pressures which it is aimed to control which themselves supply power requisite for the task. This fact will be seen to underlie all of the diverse methods suggested herein toward a solution.

56 It may be questioned as to whether this constancy of explosion pressures, even if attained, were desirable. On short cut offs the excessive cooling surface in proportion to the charge, together with the greater likelihood of dilution with burnt gases, would naturally lead to lower temperatures and pressures developing from a given compression pressure. If so, then our projected device would call for higher compression on the lighter loads and vice versa, or an overadjustment of clearance space to load. For myself, I can see no objection to this. It should improve the form of the engine's characteristic, rather than the opposite. Moreover, it is to be remembered that it will be impossible to reduce the clearance by any movable head or its equivalent to a lower percentage than about seven, corresponding to about forty-five per cent of rated load. At loads smaller than that the clearance variator will go out of commission, and the governor will then control the power quite as at present except that the now constant clearance is unusually small. The likelihood is that the engine's characteristic will be altered from the theoretic curve VV of Fig. 5 to VV'. That is to say, at these very short cut-offs the presence of surplus clearance filled with burnt gases, leading to

slower combustion and lower and later maximum pressures, would be beneficial rather than otherwise; for the prime reason for the rapid drop of the curve *VV* at the shorter cut offs is the over expansion of the hot charge below atmospheric pressure at the latter end of the stroke, because of the very small clearance needed to keep the theoretic pressure of explosion up to the predetermined point.

57 Some of the considerations just listed were brought to light during the study of designs of several forms of engine of this type which were undertaken by Messrs. H. E. Harvey, C. A. Merritt and Phillip L. Sibley in 1904, whose assistance in this connection I desire to acknowledge.

58 B The *hydraulic cylinder* as a means of clearance control might be used for the operation of the movable piston head much as it was proposed to use the screw. Since there is plenty of motive power within the engine cylinder to move the clearance piston outwardly, the hydraulic cylinder need be only single acting, containing a plunger attached directly to the clearance piston. A little pump on the engine would keep a hydraulic accumulator charged. The diaphragm operated by the little safety valve would then have only to operate a three-way cock, letting water from the accumulator into and out of the hydraulic cylinder. The accumulator pressure need be only enough to overcome the frictional resistance of the clearance piston with certainty for during the explosion the latter could settle back upon the water, which would be held by check valves, without harm; when the exhaust valve opened it would resume its inward motion, if such were needed. Such an arrangement would be far superior to the screw and worm, both in its simplicity and in the speed with which it would be practicable to operate it.

59 A slight modification of this proposal brings it into even greater simplicity. Let it be imagined that the hydraulic accumulator is set to the pressure which, taken for the area of the plunger, is the equivalent of the engine's mean effective pressure on the area of the main piston. Let the plunger be connected to the automatic controller of the accumulator pressure, so that when the plunger stands for minimum clearance the accumulator pressure will be at its least, and vice versa. Let the connection between the accumulator and the hydraulic cylinder be always wide open, without diaphragms, cocks, etc., but let it be very small—a mere leak.

60 The plunger, with the clearance-piston attached, will now act as a mean pressure indicator for the interior of the cylinder. During those portions of the engine's cycle when gaseous cylinder pressures are higher than their mean, they will overcome the hydraulic pressure

and drive some water back into the accumulator, increasing the engine clearance; but the displacement would be very slight. During the remainder of the cycle the accumulator pressure would overcome the resistance of the clearance piston and slightly reduce the clearance. The balance of these positive and negative displacements of each cycle would determine the adjustment of the clearance, increasingly or decreasingly. Under heavy mean effective pressures in the engine cylinder the clearance would be large; under lighter powers it would be small. The adjustment of the average accumulator pressure gives a ready control of the maximum pressures desired to be maintained as standard within the engine.

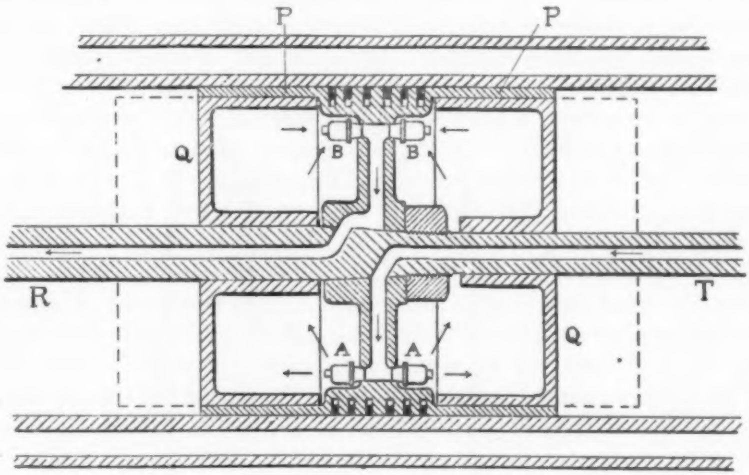

FIG. 6

61 There is imaginable, however, still another suggestion for a hydraulic control of clearances, which may be better yet. All large double acting gas engines are equipped with a water circulation through the piston-rod, piston and tail rod. If this circulation system be utilized to carry hydraulic power to clearance pistons situated directly on the face of the main piston, the cylinder heads will be left undisturbed and free for the best arrangement of valves, igniters, etc., as at present. Such an arrangement is shown diagrammatically in Fig. 6. It portrays the jacketed main cylinder and heads of a horizontal double-acting gas engine, all valves, etc., being omitted from the sketch.. The main piston *PP* is shown, attached to the piston rod *R* and the tail rod *T*, both of which are hollow. The main

piston structure is equipped with two followers *QQ* which are long enough and work freely enough within the main piston to act as clearance pistons. When these followers are in their innermost positions, as drawn, the engine's clearance spaces are at their maximum; their distention to the positions shown in dotted lines reduces the clearance to a minimum. For their actuation the tail rod brings in water from an accumulator under merely sufficient pressure to overcome the friction of the followers in the main piston, in which they work with a merely water-packed joint. This water finds access to the piston body through the spring check valves *AA*. The spring check valves *BB* permit the egress of this water through the piston rod *R*. The latter may be loaded to a resistance equal to the desired explosion pressure or, what is better, they may open freely, while the desired resistance is imposed upon the exit conduit outside the cylinder, where it is accessible for adjustment.

62 In operation, a little water will enter from the accumulator and distend the piston slightly during each suction stroke of the engine, until the resultant decrease of the clearance so crowds up the explosion pressure that an equal amount of water is driven out through *BB* each cycle. The amount of water admitted each cycle will be determined by the set of the admission cock. When the governor opens up a long cut off on the suction stroke and produces a heavy explosion more water than this will be driven out each cycle and the clearance will grow into correspondence with the cut off. When the governor reduces the cut off and the violence of the impulse, less water than this, or possibly none at all, will be driven out each cycle, and the piston will slowly distend until clearances are properly reduced.

63 As to constructive difficulties which may be foreseen, the most obvious one is the leakage of water past the followers. Yet, if it be remembered that the gaseous pressure within the cylinder, which alone places the water under stress, is also exerted at the joints between piston and follower, forcing the water back through this joint as forcibly as it squeezes it out, it will be seen that the only tendency to leakage is that due to the gravity of the water itself; which ought to be controllable with comparatively easy fits between piston and follower.

64 C Variation of clearance by *water pockets*. It is in this class of clearance-variators that is found the only instance of the actual construction of a variable clearance engine known to the writer. This is the engine exhibited in London in 1903 by Mr. Adolph Vogt, and illustrated and described in London "Engineering" of January 8, 1904.

For convenience, a diagram showing the general idea underlying its design is reproduced in Fig. 7. The engine's operation relies upon the interposition of a body of water between the piston proper and the explosion. As the piston reciprocates, the surfaces of the two bodies of water, at head and crank ends of the cylinder respectively, move up and down alternately. Above them are formed the explosion chambers, equipped with the usual igniters and valves. In such an engine any variation in the quantity of water on hand obviously varies the effective clearance. The means already suggested for the hydraulic control of clearance might be applied directly to these

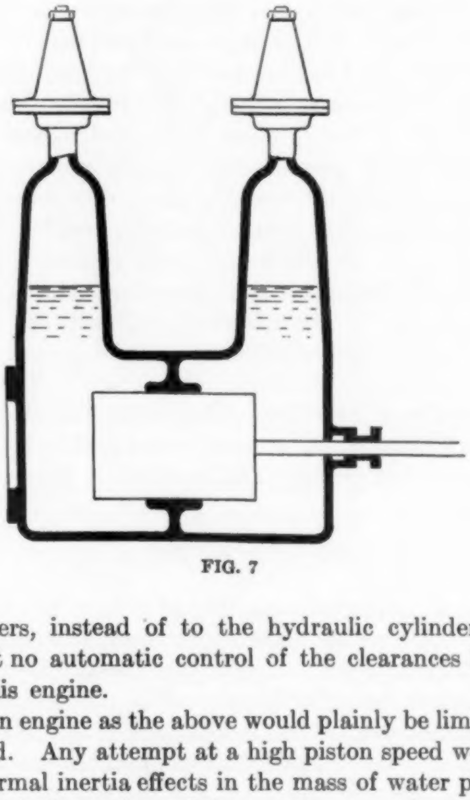

FIG. 7

water chambers, instead of to the hydraulic cylinder. I believe, however, that no automatic control of the clearances has yet been applied to this engine.

65 Such an engine as the above would plainly be limited narrowly as to its speed. Any attempt at a high piston speed would not only develop abnormal inertia effects in the mass of water present, but it would so disturb the surface of the water as to seriously affect, if not destroy, the explosive action. As a riddance of this trouble the writer has suggested (previously to the appearance of Mr. Vogt's engine) a form of engine quite like Mr. Vogt's, but turned the other side up, with the two horns of the cylinder turned down and become

water pockets. In such an engine only the piston would move, while the water remained at rest at the bottom of the pockets. The valves and igniters would of course be removed above the surface of the water. He has also suggested one or two forms of outside-compression engines (that is to say, engines having the compression performed completely in a cylinder separate from the explosion-cylinder) in which the clearance spaces of both the exploder or motor cylinder and of the compression-cylinder were in the form of pockets containing water.

66 But against all of these plans for the presence of a body of water within the explosion cylinder, against the surface of which the explosion is to occur, there is to be urged a general objection which may be overwhelming. It is to be remembered that in the Otto type gas engine the storage of heat in the walls by the working charge is as beneficial as in the steam engine it is harmful. During the first period of combustion the cylinder walls absorb heat which must otherwise be wasted, because of its intolerable temperature; and later in the expansion stroke the working gases rely considerably upon this stored high temperature heat for their support.[1] This action is a fundamental factor in the efficiency of the engine; but it would be quite impossible of occurrence with the water surfaces suggested.

67 This, so far as the writer is aware, exhausts the list of general methods proposed for the actual variation and control of clearance, although many minor modifications may be found. The next method in order for consideration is one which varies the clearance only in effect, instead of literally; but its results offer a wider promise than do any of the preceding plans. This method is that of the use of outside compression.

OUTSIDE COMPRESSION

68 Imagine a gas engine consisting of at least two cylinders, one devoted solely to compression and the other solely to combustion and expansion. The compressor would most naturally be double acting. The exploder might also be double acting; or two single acting exploders might be fed by one double acting compressor.

69 Here, to forestall misunderstanding, we insert a parenthesis to the effect that the machine in mind is not the ordinary two-cycle or Clerk-cycle engine, which performs only a little compression in the feeding-cylinder—only enough to blow the gases into the motor-

[1] See the writer's "Entropy-analysis of the Otto Cycle," Trans. Am.Soc.M.E. 1903, and his "Thermodynamics of Heat-engines," page 300.

cylinder—and then loses it all when the transfer takes place; for such an engine finally performs all of the compression in the exploder. In the proposed engine the compressing cylinder is to discharge the fuel and air into the explosion cylinder at the full pressure predetermined as the one fit for ignition and explosion to take place.

70 Nor, this being the case, is the new engine to burn the charge continuously at constant pressure, either between the cylinders or as it enters the motor cylinder, as was the case in the old Brayton engine. The new engine is to transfer its charge of gas and air, fully compressed, and the two preferably compressed separately, from compressor to motor cylinder unignited. After a suitable portion of

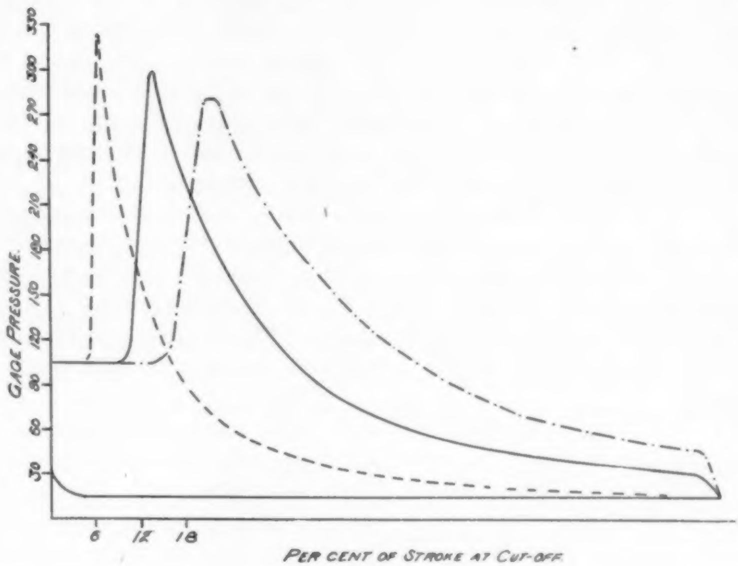

FIG. 8

explosive mixture has been taken into the motor cylinder, the supply is cut off and is simultaneously ignited. Explosive combustion at nominally constant volume then ensues, although the piston is really in motion, and after that expansion may proceed as in any engine, to any predetermined degree; the latter, as in the steam engine, depending, only on the cut off.

71 The theoretic indicator-card developed by such an engine, under different loads, is shown in Fig. 8. The full line card is supposedly that at normal load, the broken line card one at fractional load and the broken and dotted card one under overload.

72 It will be noticed that such an engine would be working upon what is virtually a Lenoir cycle operated at high pressure. Now the old Lenoir cycle was in several respects the best cycle which we have yet had before us. It gives an impulse at each stroke, yet with none of the doubt as to the mixing of fresh charge with burnt gases which is incidental to the hurried "change cars" of the two cycle Otto engine. It permits the governor to decide as to the energy of each impulse *after the engine stroke for that impulse has already begun*; which we found to be one of the marked lacks in the existing gas engine. It permits any desired degree of expansion to be attained, without incidental variation in the degree of compression (if there be any), which is another marked lack in existing engines. It will be seen shortly that if it be equipped with this outside compression it also lends itself easily to the duties of a reversing engine, which is a third impossibility with existing engines. The only thing which was wrong with the Lenoir cycle was its inefficiency due to lack of compression—which lack we now propose to make good—and its overheating, which modern methods of design can now take care of.

73 As to the probable efficiency of such a "high-pressure Lenoir" engine as has just been proposed, a short investigation of its probable variation with the change of load, so far as it may be revealed by such diagrams as those of Fig. 8, shows it to be characterized by a curve quite parallel with that of Fig. 5 labelled VV', the same as that of the variable clearance Otto engine, and quite superior to the best modern practice.

74 There is an operative limitation to the value of this new high-pressure Lenoir engine, however, which prevails quite independently of its glittering promise in the direction of efficiency. This is its limit in practicable speed. It is obvious that the period of time available for closing the admission valve and igniting and fully burning the charge, in such a way as to have the combustion occur explosively, in spite of the fact that the piston is in motion with mid stroke velocity, demands great rapidity in the performance of these events. The situation demands some ingenuity in the gear for carrying out these functions, and at the best a moderate speed of rotation for the engine.

75 As to the gear needful for performing the causative part of the task, it is thought that that can be supplied by proceeding upon the plan of igniting while the charge is still flowing freely in through the admission valve, and then arranging to have the ensuing explosion close the valve. Such a procedure eliminates the serious problem of how to keep always in proper adjustment the relative timing of cut

off and ignition, if both were to be left to mechanical causation. Yet a limitation of the speed of rotation below that common in many types of modern gas engines would still prevail.

76 On the other hand, there are many services in which this limitation would not be a serious one. In the first place, the limitation is not in piston speed, but in rotative speed; for the period available for combustion must be small only when compared with that required for the completion of the stroke. This proclaims immediately the fitness of the cycle for large engines. And if it be urged that in the cylinders of large engines the period of inflammation is greater than in smaller ones, the natural reply is that the plan of ignition at more than one spot in the compressed charge as a means of hastening inflammation, has never yet been fully investigated, because never yet needed.

77 This new type of high pressure Lenoir, when a complete unit in itself, must always embody a compressor cylinder. This is no bar in the line of cost, because any gas engine which is to develop an impulse each revolution must possess two single acting cylinders anyhow.

78 The necessary presence of a compressor cylinder makes the high pressure Lenoir an engine preëminently adapted for blowing or compressing. For the latter service the compressor cylinder would merely be made abnormally large, to serve the double purpose of supplying its own motor cylinder and the outside mains also—so large as to absorb all of the power of the motor cylinder, leaving none for distribution by the shaft in mechanical form.

79 For the task of blowing, where the pressure of discharge is considerably below that fit for explosive combustion, the engine would be equipped with a small compressing cylinder drawing its suction from the discharge main of the blower. This would supply the motor cylinder with a charge compressed to a degree which is now impracticable because of danger from preignition. If the intercooling between blower and compressing cylinder were complete, present limits of compression could be transgressed by two or three fold without danger. Even with single-stage compression it is to be pointed out that the outside compression engine would permit a higher compression than is now safe to use; for the charge at the beginning of compression would then be at atmospheric temperature, instead of at the 120 to 150 degrees fahr. which is usual when the charge is taken into the combustion cylinder for compression.

80 It is next to be noted that it is not necessary for the compressor cylinder of the high pressure Lenoir engine to be an integral

part of the machine which carries the mechanical load. A single central compressing cylinder may feed, through a system of mains, a dozen or more distinct and separate engines scattered about a mill, each consisting of an explosion cylinder only. Some of these secondary engines might be used for continuous rotation at constant speed, for generating current or driving shafting. Others might be hand controlled reversing engines, actuating rolls, etc. During reversal such engines would be actuated, for a fraction of a revolution or so, solely as a compressed air motor, the fuel supply being cut off temporarily. So soon as rotation in the reversed direction had proceeded sufficiently so that any one cylinder of the engine, if it were multiple-cylinder in form, had gotten its charge of fresh explosive mixture, explosive combustion might be again relied upon as the source of power. The possibilities of this system of gas engine design for steel mill drives, where compressed air, electricity and reversible roll drives are all needed and where cheap gas is usually available, appears to be enormous.

81 Nor is it necessary to have the engine divested of its compressor in order to have it reversible. If the compressor were fitted with automatic valves it would operate equally well with the shaft rotating in either direction.

82 This type of engine and its cycle have been foreshadowed by a number of inventors. Their patents, however, are vague and inaccurate in their statement of the results to be attained, the difficulties involved and the method of their surmounting, although they describe in each case a mechanism which, if run slowly enough, would develop this high-pressure Lenoir cycle. They quite fail, too, to indicate the possibilities of the engine when properly worked up into a system of mill-power, with its units specially designed to attain a proper piston speed. Some of these patents concern the application of the cycle to automobile service, for which it is manifestly unfit because of its fundamental limitation in speed of rotation.

83 It is sufficient to the title of the present article to have pointed out at least one non-existent type of gas engine which is hardly more than a modification of the existing Otto type engine and which is yet capable of as delicate regulation, and by the same means, as is the steam engine. It is of an additional interest which is by no means merely incidental that such a gas engine would also possess, alone of all existing gas engines, a characteristic curve of efficiency similar in form to that of the steam-engine, and an ability to transmit and subdivide power for various purposes which is neither exceeded nor equalled by the steam-engine.

The Joule Cycle, and Combustion under Constant Pressure

84 All existing gas or oil engines except the Brayton, the Diesel, the Gardie and perhaps a few others of less importance, and all the hypothetical engines hitherto discussed in these pages, have relied upon combustion at virtually constant volume, with pressures rising in explosive fashion, for their motive heat. Contrasted with this, however there is another method of combustion which has long been before the public in one form or another and which has always attracted a large number of inventors. This other method relies upon combustion under constant pressure, with an increase of volume only, rather than upon combustion under constant volume with increasing pressure.

85 I do not know the complete history of this general idea. So long ago as 1807 such an engine was proposed by Sir George Cayley,[1] and was afterwards developed by Wenham and Buckett, in England. This engine used an enclosed furnace containing a coal fire, through which compressed air was forced in a quiet current. In passing through the fire the air became heated by its own combustion and expanded in volume. The products of combustion passed from the furnace into an expansion or motor cylinder, where they developed more power than was absorbed in their compression. The net difference was available for outside work.

86 Later in the nineteenth century Joule is said to have proposed quite independently, the cycle consisting of these four processes, namely:

a The compression of atmospheric air;
b Its heating under constant pressure with increasing volume;
c Its expansion in a motor cylinder larger than the compressor;
d Its exhaust to the atmosphere for condensation.

This cycle contemplated the transmission of the heat through the envelop of the working air, as was done in the Stirling and Ericsson hot air engines, instead of the development of the heat by internal combustion.

87 It is doubtful if Joule deserves the credit of having the general constant pressure cycle named for him; but for want of a more just appellation, we shall here call it the Joule cycle.

88 Yet, in spite of this long continued interest in the general plan, there is today no representative of it successful upon the market. The Brayton, although temporarily quite popular, could not compete

[1] See Ewing's "The Steam Engine," page 365.

with the Otto engine which appeared in 1876. The Gardie, a French engine using a gas producer under pressure between the compressor and the expander, is considerably advertised abroad, but has failed in at least one attempt to enter this country. There is no other representative of the type which has attained to even this degree of commercial prominence.

89 The Diesel motor is sometimes spoken of as such, but it is not. There is some combustion under virtually constant pressure incidental to its action, but that is later vitiated by combustion "under constant temperature;" and the machine is so special in its manner of ignition and its range of pressure that it possesses less of the characteristics which are naturally attendant upon continuous combustion under constant pressure than does almost any other engine. Indeed except for features of advantage and disadvantage connected solely with the question of fuel used, the Diesel stands as an extreme and special high pressure development of the Otto type, rather than as a first step toward the broad development of the gas engine toward a type similar to the steam engine.[1]

90 It may be said broadly, therefore, that we now have upon the market no successful representative of this broad class of gas and oil engines. It is proper to inquire, first, why we should expect to have one, and secondly, why we have none.

91 In answer to the first query, imagine the mechanical combination illustrated diagrammatically in Fig. 9. A compressor or compressors feed air and fuel into a closed system leading to a heat insulated furnace, and beyond the furnace is an expansion cylinder driving both the compressors and the shaft. Therein, *C* is the compressor, *F* the enclosed furnace, *M* the motor cylinder and *S* the driven shaft. *R* is a reservoir of considerable volume, which may or may not be included in the system. For the present all questions of construction, durability, etc., will be neglected.

92 In such a system the valuable features arise from the ease with which the power may be varied, either in quantity, speed or direction of rotation, without appreciable effect upon the perfection of combustion occurring within *F*. *F* is white hot inside, instead of

[1] The writer has long taught his students that the remarkable efficiency of the Diesel engine could be closely paralleled by any designer of Otto engines who chose to incur similarly high pressures. Since these pages were written a preliminary report from Professor Burstall, of the Gas Engine Research Committee of the British Institution of Mechanical Engineers, tells of an indicated efficiency of over 41 per cent gotten from a very small Otto engine by using a compression of 200 pounds. This he calls "Diesel efficiency."

being water jacketed, so that poor mixtures of fuel and air may not get through unburned. It has no rapidly moving piston to determine how fast the combustion must proceed in order to be useful. The current of combustible fluids may pass through *F* fast or slowly, provided its capacity be not exceeded, and in lean or rich mixture; yet the heat will always be developed. Then, too, the action in *F* is unconscious of whether *S* be rotated in one direction or the other. A given volume of fluids may be passed through *F* by a small high speed machine or a large slow speed one, or the compressor may be of one type while the expander is of another. Indeed, the compressor and expander are not necessarily parts of the same machine. Yet practice shows the combustion to be unaffected. It may be said, in general, that continuous flame combustion takes place much more readily under high pressure than under atmospheric pressure.

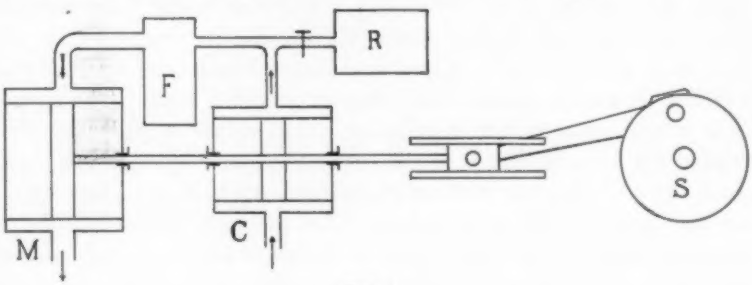

FIG. 9

93 Let us suppose, now, that cylinder *M* normally develops 167 horse power. Normally about four-tenths of this, or 67 horse power, would be absorbed in compression, leaving a net 100 horse power for the shaft *S*. If the governor of the machine is able to vary the power of *M*, in steam engine fashion, from zero to twenty per cent above its rating, then, as it did so, the net power of the machine would vary as follows:

MOTOR'S POWER	COMPRESSOR'S RESISTANCE	NET POWER DELIVERED TO SHAFT
Horse power	Horse power	h. p. and per cent of rating
200	67	133
167	67	100
133	67	66
100	67	33
67	67	0
33	67	−34
0	67	−67

94 Of course, the figures in the last column above zero and below the maximum imply the presence of some means for by-passing the unneeded air around the furnace, which is easily done. Those below zero imply the storage of compressed fluids in the reservoir, which could not continue indefinitely; yet for temporary purposes it would be of great use. The machine therefore possesses a wider range of power than even the steam-engine. Its regulation, too, would be exactly that of a steam engine, both in promptness and in delicacy. Why, then, has no engine of this type succeeded?

95 First, as to efficiency. The efficiencies of the constant-pressure and the Otto cycles are *theoretically* the same at the same degree of compression. It is this fact which has led all the earlier constructors in this novel field, down to the present time so far as I know, to adopt the same degree of compression as that prevailing in the Otto type engines of their day, usually six to eight atmospheres. But it is a striking characteristic of the constant pressure type that its "fixed charges" of frictional and thermal loss, and especially the former, are much greater than those of the Otto type. The proportion of the gross power developed in the motor cylinder which is needed for compression is much larger than in the Otto type, being some forty or fifty per cent as compared with twenty or twenty-five for the latter. This resistance is fully included in computing the theoretic indicated efficiency, but its incidental friction and commercial cost are not. Just as the Otto type, with its moderate proportion of compression, has a much poorer mechanical efficiency than the steam engine, which has no compression of its fuel and air at all, so the Joule type, with its magnified amount of compression, has a mechanical efficiency still poorer than the Otto.

96 In addition to this greater proportion of power going to compression, the surface swept over by the pistons of a Joule type engine, per unit of power developed, is much greater than in the Otto. Fig. 10 is designed to show this. In Fig, 10 *ABCDEFB* is the indicator-card of an Otto engine. *MBCNM* is the card of the compressor cylinder, and *MNQSTM* is the card of the motor cylinder, of an equivalent Joule type engine. The distance traversed by a piston of any given diameter, in developing work from a given amount of fuel at a given degree of compression in the two cycles respectively, is that measured by twice the distance *AB* for the Otto cycle and *MB* plus *MT* for the Joule, or in the proportion of two to three.

97 It is the two obstacles of friction and cost involved in this unusual transmission of power from motor to compressor, and of fluids from compressor to motor, which have always kept the constant

pressure engine out of use. No machine of that type may hope to succeed which does not transmit the power needed for compression directly from the motor piston, without transfer through oblique rods, slides and cranks, or to a fly wheel and back again. As a resultant of this, also, no machine of that type which does not carry its compression very much higher than that customary in the Otto type, so as to develop an indicated efficiency so high that it can afford these losses just mentioned, may hope to compete.

98 Yet there is hope even here. In the Joule cycle compression is not limited by anything like the narrow bounds which confine it in the Otto. In the latter the maximum pressure which the mechan-

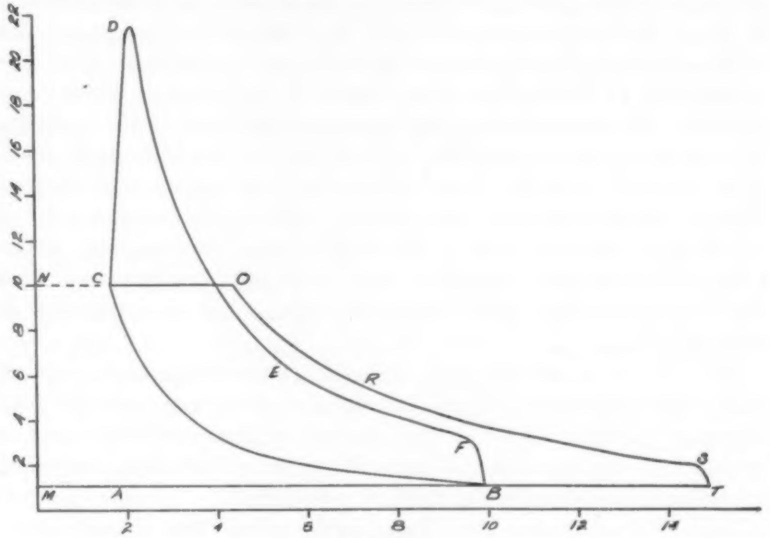

FIG. 10

ism must stand is, upon occasion, three or four times the compression pressure; while in the Joule engine it is merely the compression pressure itself. This being so, it might seem impartial to the two types to compare them with their maximum pressures, rather than with their compression pressures, alike. If we do this we must have the Joule cycle compressing to some 350 pounds per square inch, or about twenty-five atmospheres, and burning at that pressure. Its theoretic efficiency would then be a third better than it was when compressing to only eight atmospheres.

99 With this gain in theoretic possibilities the Joule cycle has some chance for successful competition. It has been the experience

of both myself and others, so far as I am acquainted, that a working-pressure of at least five atmospheres must be attained before a Joule engine has any likelihood of being able to develop enough net power to overcome even its own resistance; but from that pressure upwards the gain of power and efficiency with increase of pressure is rapid. The "fixed charges," both thermal and frictional, have then been met. Nearly all the increase in theoretic power due to the increase in pressure is available as actual power.

100 That is to say, the theoretic efficiency of the Otto engine compressing to eight atmospheres is about 45 per cent, of which about one-half, or 23 per cent, is actually available on the shaft. The theoretic efficiency of the Joule engine compressing to five atmospheres is about 37 per cent, none of which is available at the shaft. But when compressing to twenty-five atmospheres the theoretic efficiency of the Joule engine is about 60 per cent. If we now deduct the losses incurred at five atmospheres, which have not been appreciably increased by the rise in pressure, the net result is 23 per cent, or about on a par with the Otto type. The maximum pressures of the two engines are also about equal. So the two cycles are about equal in efficiency when worked to the same maximum pressures. Comparative superiority, therefore, must be fought out between them along considerations which are purely mechanical or commercial in their nature.

101 But here arises a fresh obstacle. Generations of experience with steam engines has taught us that the piston and cylinder may not be used profitably for so wide a range of pressure as from one to twenty-five atmospheres. If greater ranges of pressure than that are to be used compounding must be resorted to.

102 To be sure, the Otto type of gas engine starts its expansion at a pressure of twenty-five atmospheres and incurs atmospheric pressure on the back stroke; but it gives up further expansion when a pressure of three or four atmospheres is reached. The Diesel comes nearer to doing it, for it starts its expansion at nearly forty atmospheres and stops at only two or three. Both machines handle atmospheric pressure during their suction stroke. Both of them, too, pay heavily for their infraction of this fundamental rule in engine-design, in their excessive first cost and uncontrollability as compared with the steam engine.

103 Now it is only by its promise of approach to steam engine standards that the Joule cycle holds forth any inducement to patronage. Therefore, if it is to work successfully to twenty-five atmospheres it must be compounded on both the compression and the

expansion side. To supply compounding on the compression side is easy—easier than to withhold it, at twenty-five atmospheres. But compounding on the expansion side is another and a much more difficult matter. Apparently no person has ever yet succeeded in expanding the products of internal combustion through two stages or cylinders, and in deriving any decent proportion of the power theoretically to be expected from the second stage. The best which has been accomplished has been to get the low-pressure piston to overcome its own friction, and sometimes not even that.

104 The reasons for this are explainable by the same phenomena which were referred to in connection with the unfitness of water for direct contact with the working gases of an explosion engine, namely, the very rapid heat interchange which takes place with the envelop when these very hot gases are concerned, and the extreme sensitiveness of their particular form of heat motive power to the abstraction of heat. The heat stored in the walls by the flame in the locality of combusition is a marked source of power in the ordinary or non-compound Otto type gas engine. Its lack in the low pressure cylinder of a compound explosion engine is the source of the chill which is always revealed by the collapse of the gases as they enter this cylinder in such engines. The discussion of this phenomenon, in its general bearing upon the problem of compounding an internal combustion engine, amounts to saying that the dry working gases of such an engine possess too much temperature and *too little entropy*, or heat mass, to stand up for themselves when transferred from the place of their birth to a strange locality. In order to solve the problem we must give to the working substance enough entropy to give it carrying power.

105 Now a decrease in temperature and an increase in entropy is the easiest thing in the world to accomplish. It is an incident to every instance of heat conduction. Moreover, as the evaporation of water into steam involves the greatest increase of entropy of any familiar phenomenon, and the resultant temperature of the process is automatically controlled by the prevailing pressure. Let us, therefore, exchange this unstable and evanescent heat of the hot gases for stable and reliable steam heat of a lower temperature, which will carry through a succession of cylinders when the other will not. Moreover, the products of combustion are too hot to be handled efficiently in a lagged cylinder, the drop in temperature is in itself an advantage.

106 Therefore let us use the products of combustion to make steam before attempting to drive a piston with them; and since they are

already under the pressure at which the steam is to be used, their heat is most conveniently transferred to the water by actual contact. To effect this the flame may be generated upside down over water and, so soon as combustion is complete, plunged therein. Fig. 11 shows in diagram form what the furnace develops into along this line.

The question which arises as to the effect of this device is, may we expect to gain enough in availability from our gain in entropy to make up for our loss of availability in our loss of temperature?

107 I think that we may. The reasons for the belief are shown in Fig. 12. This diagram displays, first, the comparative theoretic efficiencies of the Otto and Joule cycles respectively, when both work

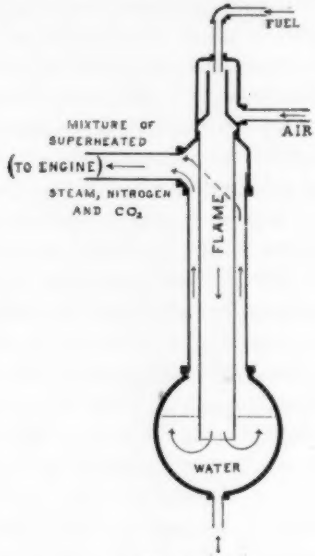

FIG. 11

to the same maximum pressure. The Otto cycle is drawn for a compression of 103 pounds by gage, exploding to 350 pounds. The Joule compresses direct to 350 pounds. Both cycles represent the action of about one pound of working substance, receiving 1000 B.t.u. from the fuel.

108 The Joule cycle, *ACEGA*, almost completely encloses the Otto cycle *ABDFA*. But both are extremely high temperature cycles. In the Otto cycle high temperature is valuable, to a certain degree, until compounding is undertaken. Then all its value is lost. The same would apply to the Joule; but in the latter, *compounding may never be dispensed with.* At the same time, temperature

loss and entropy gain is possible in the Joule, while impossible in the Otto cycle.

109 Fig. 12 therefore shows, also, the conversion of the high-temperature narrow entropy heat of the Joule cycle, by means of the apparatus of Fig. 11, into the resultant low temperature wide entropy

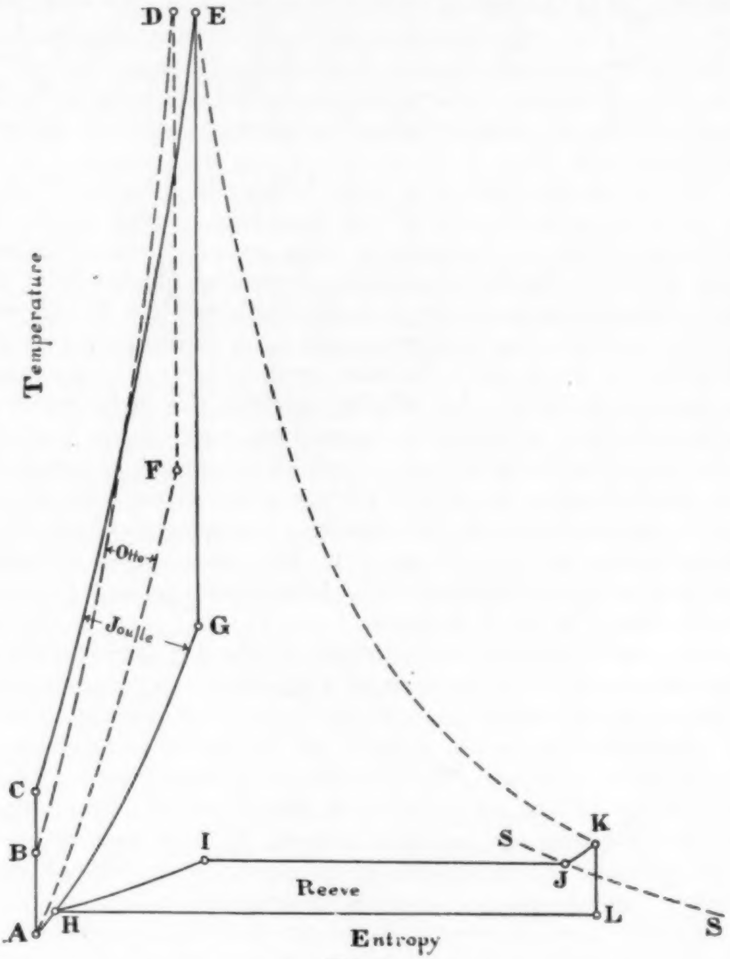

FIG. 12

cycle *HIJKLH*, which displays the thermodynamic action of the mixture of nitrogen, carbon dioxid and superheated steam which is discharged from the generator of Fig. 11, to serve as a working substance in the expansion cylinders. That is to say, the heat exchange

occurring in the generator is shown by the free fall or constant heat curve *EK*.

110 The tremendous reduction in the temperature drop within the engine, with its inevitable advantages and disadvantages, is visible at a glance. The point of interest is that, whereas only a fraction of either of the original cycles is actually available for work, both being subject to heavy water jacket losses inseparable from high temperatures, the reduced area of *HIJKL* is virtually all available for work. It has neither the great temperature differences of the gas engine nor the wet steam of the saturated steam engine to promote activity of wall loss.

111 In practice, this plan fully justifies its theory. That is to say, it gains controllability and reliability; although whether at too great an expense in other directions cannot be known without lapse of time. The steam generator or cooling chamber holds the temperature of its composite discharge stable within a few degrees, under wide fluctuation in flame; yet this stable temperature is readily altered by an alteration in the water level, which is of course maintained automatically. As actually operated this temperature is most readily held at about 550 degrees fahr., a point already empirically reached in steam engine practice with superheated steam as the one most conducive to safe and efficient action within the cylinder.

112 As to compounding, the success of the principle of providing ample entropy is more striking still. The power carries over into the low pressure cylinder perfectly. This cylinder not only performs its full share of the work, but more.

113 For instance, for the purposes of adjusting the processes of combustion, our chief experimental engine was run for some time with a supply of factory steam in the low pressure cylinder, to keep the compressors in motion without relying upon the engine's own motive power. The full capacity of the compressors was then being run into the furnace, under full pressure, and burned. The furnace was white hot inside and well lagged outside. Combustion was known to be complete. Every heat unit in the normal fuel supply was being developed and thrown into the high pressure cylinder.

114 But as yet no water had been supplied to the spherical pot of Fig 11. No steam was being made. In consequence the engine showed no sign of life, when the power derived from the factory boiler was shut off, although the Joule cycle of Fig. 12 was being performed as perfectly as possible.

115 Then *cold* water was pumped into the pot, up against the down-coming flame. It would seem a most natural expectation that

under those chilling circumstances the last vestige of power developing effect from the gas flame would disappear. Yet, on the contrary, the cold water had no sooner reached the flame than the engine showed every sign of a life and power of its own, picking up speed and accumulating pressure independently of the outside power.

116 There could be no more striking illustration than this of the fact that entropy, or heat mass, is the thing about heat which is of equal avail for doing work with temperature drop; if, indeed, it be not sometimes *more* effective; just as mechanical mass is often of equal or greater avail for doing work than is velocity. For instance, when we wish to drive a pile effectively we do not take a tack hammer and give it the velocity of a rifle bullet downward on the end of the pile, in order to embody in the tack hammer the requisite amount of kinetic energy. Yet such a procedure is an accurate analogy to the use of the white-hot, but thin, molecules of the hot dry gases of a gas-engine flame, impinging against the piston with the enormous velocity of their bright heat, but with little entropy or mass, as a means for its propulsion.

117 In the case of the pile we take, instead of the tack-hammer, a ton of iron; and we drop it on the pile-head with a velocity lower than a boy can give to a stone. Yet the pile moves; whereas under the tack-hammer it would not. Similarly, when we throw against the piston and cylinder walls the four fold more massive molecules of steam heat, even though moving with less than half the velocity of the flame molecules, the piston responds with a steadiness of real power which the gas engine piston knows nothing about.

118 The importance of the choice of proper mass for the performance of mechanical work is unquestionable. One of the first lessons learned by the boy in the shop is the selection of a proper weight of hammer for each job. All through the problems of engine design mass is a prime factor. Yet mass is of no more importance in mechanics than is entropy in thermodynamics. It is as impossible to proceed intelligently in the solution of thermodynamic problems, without a finger-end concept of entropy, as it is to do good work in mechanics uninformed as to the reality of mass.

119 Anyone who has ever watched the prow of a massive ship forge slowly through the crib work of a wharf with which it was in collision, most deliberately yet almost irresistibly, will never say that there is no such thing in mechanics as mass. Yet the thing has been publicly and repeatedly said. It is similarly difficult to understand how anyone who has studiously watched steam at work, its entropy doing thermodynamically just what mass does in mechanics,

can ever say that entropy has no physical reality, or that it is of secondary interest to temperature in the study of thermodynamics.

120 In the engine recently referred to, the low pressure cylinder, which was over three times the volume of the high pressure cylinder, developed, when thus properly supplied with entropy, more power than the high pressure cylinder. Its proportion of power was as readily adjustable, by controlling the receiver pressure by means of the low-pressure cut off, as is the case in any compound steam engine.

121 The form of engine which was developed to carry on this cycle is worthy of brief mention. The problem of its design was stated in advance as follows:

a To provide for compound compression and expansion within a single machine;

b To transmit power directly from expander piston to compressor piston;

c To connect all pistons to a single crank and maintain proper constancy of crank effort;

d To follow standard steam engine construction, so far as possible.

122 While it has since been discovered that this statement of the problem was too rigid in some particulars, yet such it was supposed to be at the time that it confronted us. In its solution the third item of specification proved to be the most troublesome. Any possible arrangement of compressor and expander cylinders in tandem promised to give an abnormally vigorous impulse to the crank early in the stroke, followed by a vigorous negative pull on the crank shortly after midstroke. This phenomenon is a familiar one in all steam driven air compressors; but there, the air compression being the only duty, marked variations in speed are not objectionable. With us, however, compression was a merely incidental duty. The main task, the development of outside power, demanded an even speed and a constant crank effort.

123 The problem was finally solved by the arrangement of parts shown diagrammatically in Fig. 13. Therein *HM* is the high pressure motor cylinder, *LM* is the low pressure motor cylinder and *C* is the compressors, driven from a single cross-head. The underlying ideas were:

a To set the low pressure motor, which should normally develop one half the gross power, to driving the compressors, which, with their friction, might be expected to absorb almost one-half the same;

b To reserve the high pressure motor for driving the main shaft, quite as in an ordinary simple steam engine;

c To have the compressors so timed, with dead centers occurring ahead of those for the high pressure motor, that the former would develop their heavy resistance while the latter were still young and vigorous in their stroke;

d To develop the inertia forces needed to equalize the varying fluid pressures by heavy reciprocating rather than by heavy rotating masses.

124 All of this was accomplished by the use of a heavy triangular cast steel connecting rod for connecting the high and low motor pistons with the crank, and by setting the compressors tandem to the latter. This connecting rod served as a clearing house for all surplus or deficit of forces arising in either the upper or lower department. Late in the outward stroke the deficit below and the surplus above

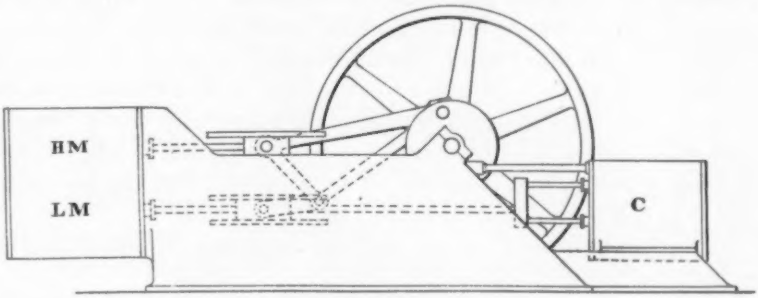

FIG. 13

combined in the triangle to develop a downward pressure on the crank pin. Late in the inward stroke they developed a similar upward force. The crank pin thus not only escaped all negative pull during its horizontal motion, but it experienced positive propulsion across dead centers as well.

125 Finally, the engine was equipped with double acting cylinders all around, with piston valves to the motor cylinders and with a Rites shaft governor for their control. The motor indicator cards were those of a standard compound shaft governor steam engine. The regulation was, of course, that of the automatic steam engine. Any other steam engine valve gear, including reversing gear, could have been used as well as that which was used. The motor cylinders measured 7 by 18 inches and 12 by 19 inches respectively; cylinder ratio, 3.22.

126 The exhaust from this engine looked exactly like that from a

steam engine. In fact, however, it was quite different. Its temperature, instead of being the 212 degrees fahr. which was called for by the barometric pressure, had it been pure steam, was well down toward the temperatures common in the exhaust pipes of condensing steam engines. Had the conditions of operation been more perfectly under control than is commonly the case with experimental engines, it might have been sent there.

127 Now it is a fact familiar to all versed in thermodynamics that the vacuum exhaust of a condensing steam engine is undertaken, not for the sake of the lowered back pressure, as was originally supposed, but for the sake of the lowered exhaust temperature; which, in the special case where steam is the working substance, cannot be procured without lowering the pressure below atmospheric, by means of the air pump and condenser. But this is a troublesome and costly process which is tolerated solely because it permits the exhaust temperature to be dropped from 212 to 125 degrees. It is the temperature range within the engine which measures its efficiency, not its pressure-range. On the other hand, it is the entropy range within the engine which measures its capacity, or power; and it is because the steam engine, with its restricted temperature range and much derided efficiency, possesses an enormous entropy range that it was the first to come into use, that it stands today the superior of the gas engine and that it will stay with us to the last.

128 Now in the engine just described there exists this combination of features, namely:

a An engine using liquid or gaseous fuel (that is, dispensing with the coal pile, pressure-boiler and grate),

b Developing its heat by a form of combustion, viz: a flame burning continuously under high pressure, which it is difficult to make imperfect and which is always more perfect than in the explosive type of engine, and

c From that white-hot combustion developing the sturdy entropy of steam heat, yet without the burdensome presence of a steam boiler under pressure or of the transmission of heat through metals,

d Expanding that steam heat from the highest practicable temperature of superheated steam down to

e The lowest temperature of exhaust which is useful with steam, yet without the burden of a condenser, air pump or a vacuum.

f In standard steam engine cylinders capable of all the double action, delicate regulation, margin of power, reversibility,

etc., which are the standard attributes of the steam engine, and

g Involving the two additional advantages of

a the temporary absorption of negative work upon demand, and

b the transmission and subdivision of power from a central source.

129 The last item of all is the only one which has not yet been discussed, and it is the most important of them all from practical engineering considerations.

130 Immediately the imagination enters upon the field which such a prime mover might occupy in modern industrial enterprises it becomes evident that it will not be practicable, or convenient and profitable, at any rate, to equip each motor cylinder of a large system, which might include engines and services of the most diverse character, with its own set of compressors. But this is not necessary.

131 Let us imagine a central compressing plant, consisting of machines similar to the diagram of Fig. 12 but having compressors so large in proportion to the motors that there would be no surplus mechanical power after driving the compressors. Of the discharge from these compressors their own motors would absorb a minor fraction. The remainder would be available for distribution to distant combustion chambers feeding independent motors. These latter would be compound non-condensing engines of standard steam engine patterns, coming from the present builders of steam engines. They would be special only in that they would be fit for a throttle pressure of 300 or 400 pounds per square inch; their cylinders would be smaller than usual in proportion to their power and their weight of connections, etc. They would be cheaper per horse power than a standard compound condensing steam engine fit for the usual boiler pressure. They could easily be made of the most diverse types. Slow speed, high speed or reversing engines; turbines, steam hammers, pumps, etc., would all work on the same supply-system as they now do from a common boiler-plant.

132 Such a system would seem to be ideal in its elasticity of adaptation, in its freedom from all the costs and objections to the operation of a boiler plant and in its extension of the efficiency of the gas engine over the practicability of the steam engine. The wonder is, at first glance, why it has not long ago become a standard system of power development and distribution. Indeed, I believe that ultimately it will become, in essential, one of the most approved standard methods. But it has not yet done so; and it probably never will, in

just the form described. It is proper, therefore, to inquire wherein lie the unusual costs and obstacles which so beset and partially counterbalance such an attractive array of marked advantages.

133 These have already been partially stated. Most of them are involved in the greater volume of piston displacement demanded, and the incidental friction and first cost. These unusual costs will no doubt be justified, at times, by special advantages to be gained. But if the system is to be available for wide adoption they must be minimized.

134 The most obvious step to this end is the use of the turbine for the lower stages of pressure. The turbine has already signalized itself as a machine peculiarly adapted to the expansion of larger volumes at lower pressures than the piston can handle profitably. A few steam plants, particularly in France, have already carried this idea to its logical conclusion by using the piston and cylinder for the high pressure stage of expansion and the turbine for the low pressure stage; but only, the writer believes, where some special demand, such as reversibility in the upper stage, for rolling mill drives, gave emphasis to the advantages to be gained. In the central plant of an internal combustion power distributing system, such as was described, the special demand exists; and a turbine would there be used, without doubt, for the low-pressure stage of expansion.[1]

135 As to compression, however, there is less experience and more doubt, though the doubt is not a prohibitive one. Turbines have been connected directly to centrifugal fans and have developed a discharge pressure as high as five atmospheres with efficiencies ranging as high as 70 per cent; with the handling, of course, of volumes of air which are enormous in comparison with ordinary compressor capacities. Worked to even a much lower pressure than this, such a machine would so reduce the requisite piston displacement of a given plant as to bring costs and frictional losses within reason for any plant large enough to make the duplex character of the plant not undesirable in itself. The combination of high pressure reciprocating engines with low pressure turbines, which now promises to become standard practice, would be an ideal aid toward the practicability of this general plan.

136 There is another objection to the plan, however, which is more fundamental in character. This lies in the question of getting

[1] These pages were written not only before the recent decision of a British steamship company to equip one of its new steamers with a combination of high pressure reciprocating and low pressure turbine engines, but before the same plan was forecast for stationary power-plants by Mr. Henry Stott, of New York.

a cold plant into motion under load. When once in operation and hot, the margin of power, as already stated, is the equal or better of the steam engine. But for starting cold the system's reservoirs are of no avail, in comparison with the steam boiler. Nor can they compare even with the reliance of the ordinary gas engine upon a reservoir of compressed air for a start. In the explosive engine, one or two revolutions is usually enough to permit the engine to pick up its normal, or almost normal, supply of energy from the fuel. But in the constant pressure engine this is by no means so. The motive power is based upon the accumulation of a considerable store of temperature in the combustion-chamber and its accessories. Such a device will warm up more quickly than will a boiler and superheater; but the period during which combustion is maintained therein before substantial power is available is quite beyond the reach of any ordinary compressed-air reservoir.

137 In large plants a large reservoir might be used to warm up and start a little combustion chamber and engine, and that in turn used to "excite" the main engine; and where feasible at all such a plan would be entirely practicable. But it would still be a troublesome means of starting, and for the great majority of smaller plants it would be prohibitive.

138 What is wanted, then, is a self starting central plant, which shall pick up pressures in the system from atmospheric when everything is cold and do it quickly and easily.

139 Whereas the explosive cycle has been shown to be of an uncontrollable nature and unfit for the finer services which steam handles with perfect docility, yet the compression of air and gas is not one of those refined services. It needs to be performed efficiently; but it makes no demand at all for delicacy of speed regulation, nor for a wide margin of power at the motor end of the machine. Theoretically the power needed per stroke for a constant discharge pressure is constant. Actually only such variation is called for as will suffice to speed up or slow down to meet the varying volumes demanded, which is a question of machine friction only. For such a service, then, the explosive cycle, barring its demand for unusual fly wheels, is perfectly fitted. For the present, too, the present discrepancy in natural speed between gas engines and compressors will be overlooked; for a few high speed compressors have already been built with success, and more will follow so soon as a demand for them is felt.

140 In this connection some readers may recall with interest the struggles of years gone by for direct connection between steam engines and dynamos. Those who called for it were told by those who opposed

it that the two machines had natural speeds which were too far apart ever to be brought together. Yet now who ever sees a dynamo running at one speed driven by an engine running at another?

141 If we imagine, then, the central plant to consist of compressors direct driven from explosive engines, have we not the complete solution of the entire problem? The compressors, when the mains were empty, would offer no resistance but machine friction to starting; which is just the condition of affairs which makes the explosive engine easily self starting. This engine once started, pressures could be accumulated and the combustion chambers warmed up as deliberately, or almost as rapidly, as one pleased.

142 The picture becomes even more mechanical, natural and attractive if the type of explosion engine chosen for this work be the variable cut off, outside compression type, which was indicated in Fig. 8. That type was then described as preëminently adapted to compression. Moreover it will appear, if the actual design of such a central engine be undertaken, that it is urgently desirable that the expansion part of its process be divided into two stages, or compounded. For this the water filled cooling chamber, for exchanging temperature for entropy, stands ready, making the process feasible where otherwise it would be hopeless, or most difficult at least.

THE MECHANICAL ENGINEER AND THE FUNCTION OF THE ENGINEERING SOCIETY

President's Address 1907

By F. R. HUTTON, E.M. Sc.D., NEW YORK.

The convening of The American Society of Mechanical Engineers for its Annual Meeting in the splendid building devoted to the needs and uses of such a society and for the first time in such surroundings makes it seem fitting that the opening address of the meeting should consider the duty and function of the engineering society in its relation to the profession which underlies it. The speaker takes special pleasure in availing himself of this opportunity by reason of the many years of his service to such a Society and of the close touch permitted to him for this reason with the problems which the topic presents.

2 It would be an attractive possibility to consider the wide range of the Engineering Societies as they are grouped under the roof of this Engineering Building, and to discuss their functions with respect both to their own specialties and to the profession as a whole. This would open up the possibilities of the building and the significance of it as a gift to our profession in a way which would be both stimulating and suggestive; and would present the greatness of the thought in the mind of its donor in a way to make it remembered. But the limitations in space and time and the proprieties of the case make it appear fitting to confine consideration to the one field of the Mechanical Engineer, and to the function of The American Society which bears his name. This simplifies the questions into two: What is the mechanical engineer at the opening of the twentieth century; and, what are

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the duties and functions of an American Society of Mechanical Engineers to that branch of the profession? This latter logically divides into two sections; the duty of the Society to those without its membership; and the duty of the Society to those enrolled within it.

3 In seeking a defensible definition of the mechanical engineer in these days, which are those of specialization on the one hand and of broadening scope upon the other, there are several courses open. The first and obvious one is to rest upon authority and inheritance and to follow recorded standards which have some vogue or acceptance. The second is to gain definiteness of thought by differentiating the mechanical engineer from other specialists by noting what lines of professional activity are *not* his; and the third will be to scrutinize the list of membership in the Society and so dividing the members into groups to generalize therefrom as to what the man is doing who is or claims to be a mechanical engineer.

4 In turning to the historical definition, or that which has its authority from long usage, the stately language of Tredgold of England always claims first place as of right. At a meeting of the Council of the Institution of Civil Engineers of Great Britain on December 29, 1827, Mr. Tredgold, Honorary Member of the Institution, was requested by resolution to "give a description of what a Civil Engineer is," in order that this description might be embodied in the petition for a charter for such a body. Mr. Tredgold's historic definition is:

5 "Civil Engineering is the art of directing the great sources of power in Nature for the use and convenience of man." He amplifies this by adding that it is a practical application of the most important principles of natural law, and has among its objects that of improving the means of production and of traffic for external and internal trade, such applications being directed to the construction and management of roads, bridges, railroads, aqueducts, canals, river navigation, docks and store houses, ports, harbors, breakwaters, moles and lighthouses. He includes also the protection of property from injury by natural forces, as in the defense of tracts of land from encroachments by sea or rivers: the direction of streams and rivers for use either as powers to work machines or as supplies for towns or for irrigation, as well as the removal of noxious accumulations as by drainage. He touches also upon navigation by artificial power for the purposes of commerce, and adds that the scope of utility of Engineering will be increased with every discovery in natural law and physics, and its resources with every invention in mechanical and chemical art. The Charter of the Institution repeats the Tredgold wording, and describes the profession of the civil engineer as "the art of directing the

great sources of power in nature for the use and convenience of man, as the means of production and of traffic in states both for external and internal trade as applied in the construction of roads and bridges, aqueducts, canals, river navigation and docks for internal intercourse and exchange and in the construction and adaptation of machinery and in the drainage of cities and towns."

6 In comment upon this definition it may be observed:

a It should receive the respectful homage which is due to a great achievement. Its breadth and comprehensiveness show us how great was the man who created it, and so early in our industrial history. By suitably extending the meaning of its terms and by reading into them the fuller significances of the later years, the definition is still defensible for what it can be made to cover. We have not outgrown it yet, by any means.

b It should be regarded as a definition of Engineering in its broad and comprehensive sense, and should not be used to apply only to that specialized department of the profession to which in America the term civil engineering is applied in education and in popular use. What Mr. Tredgold meant was the profession of the civilian practitioner of engineering, as distinguished from the military engineer, the latter being concerned with the special problems of the fortress and the work of the army. The civilian and the military engineer have much the same problems in any case, and the military engineer in the field of ordnance becomes perforce a mechanical engineer of high order,[1] but the purpose of the Tredgold definition was to form the basis of a charter for an organization of civilians as differentiated from employees of the British Government in their own engineering field; and the qualifying word applied to the engineer should be so understood in the light of its purpose.

c In the third place it should be noted that this definition of engineering as practised by the civilian was given in the infancy or at the birth of the modern industrial epoch in which we are now living. This constitutes an element of the admiration we must feel for the greatness of its creator, that under these conditions he should have seen so far, but the fact is also responsible for the limitations

[1] See paper by Brigadier General William Crozier, Proceedings June 1907 The American Society Mechanical Engineers.

which are suggested by it and which must be removed in the light of our present clearer vision. The year 1827 was two years in advance of the competition at Rainhill where Stephenson won fame for the solution of the motive power problem of the railway: the first power driven steamboats on the Thames had been struggling against the tides only since 1813, and Dr. Dionysius Lardner had convinced all conservatives that the consumption of fuel as the standard then existed would preclude all successful working of long distance marine service such as across the Atlantic Ocean or around the Cape. The machine tool was still a small thing, whose tools were held by hand to the work to be done. Engineers were highly pleased when the fit of the engine-piston in the bore of the cylinder was so close that "at no point in its circumference or traverse could you drop a shilling through the space between the two." The mining of England while important relatively was yet limited for lack of shaft-machinery and was largely or entirely carried on by mine-bosses of experience. Faraday had yet four years to labor before he made his historic discovery of the electric current induced by motion before the pole of the magnet. The metallurgist and chemical engineer could only come into being when the needs of a community, built upon industrial production with cheap power at its base, should have called for him. What did exist were mills driven by water-power: the iron works built upon the puddling and rolling processes originated by Henry Cort, and the achievements of Boulton and Watt in respect to stationary steam engines. Nasmyth with the steam hammer and the large machine tool were still in the future; but most of all and most significant of all from the present point of view, the idea of manufacturing or production upon a large scale, in factories or shops where great groups of productive machinery were gathered together to be served by a common source of mechanical power had not yet been born. The industrial community or civilization made possible and present by the combined achievement of the physicist the mechanical engineer and the electrical engineer, in whose power house and from it are liberated, generated and transmitted the vast volumes now in use of industrial energy is truly dependent upon the powers of nature con-

trolled and directed by engineers. The implication is however that these furies of nature are in existence and active and are awaiting control and direction. The definition is silent upon that group of engineers concerned with the liberation, the generation and the transmission of forces which are potential and are not realized in nature until in accordance with the natural law some engineer has caused them to appear.

d Again, it is only by a great stretching of the inclusive character of terms, that the expression "powers of nature" can be made to include the forces which are economic or social or psychological in their application, and which come into play for control and direction when production on a large scale is under consideration, and large numbers of human beings become the organs or implements of the factory as a tool for production. The aggregation of power, machinery and producers is a unit; it is to be created, organized and operated for an end. By whom? The ordinary commercial or financial or business training alone is not adequate for proper direction and control: the learned professions of law, medicine or divinity are not suggested for the purpose; but as the engineer has created the plant in its physical aspects, he would seem the proper one to operate it in its industrial functions. The engineer has therefore become an economic factor as he was not conceived to be in that earlier day. The energies directed and controlled by such an engineer may only be included within the "powers of nature" by an effort which strains their meaning to the breaking point in unfriendly hands: he is yet a director or controller of forces, and of no insignificant type.

e The inclusion of the powers of nature within the scope of the elements of the profession of engineering carries with it the utilizing of the resisting forces created in the materials of engineering when such powers are exerted to deform them. Engineering, therefore, correctly covers the creation of structures to resist the dynamic action of forces, meeting by the principles of statics the impact or action of impressed energy. The definition might properly be extended, therefore, to cover both the adaptation of the physical properties of the materials of nature or manufacture to the withstanding of stress, and the direction and control of forces.

f Finally, he who commits himself to the splendid Tredgold definition must take its alleged defect with its excellency. It is that it includes as engineers not alone those who create and install apparatus to control and use the powers of nature, but those also who direct and control the machines or apparatus when created and installed. This will include those whom I will call "coördinators of design," who take the boilers, engines, dynamos, condensing apparatus, piping and pumps which are on the market, and combine these into a consistent whole. They have not designed any of the units themselves, or created a new machine, but they have created a power house, and are utilizing the powers of nature for the use and convenience of man. Somewhat under the same category is he who receives the finished power house with all its units from the foregoing type of engineer and his allies, the contractors who have done the construction work, and is then and thereafter entrusted with this upkeep, repair and continuous operation. Such a man also directs and controls the powers of nature, albeit on a less exalted plane than the creator or designer or the coördinator. There are those who would make the coördinator appear as a mere purchasing agent, and the operator as a mere craftsman, and neither an engineer. I cannot agree with them, believing that their function calls for skill and acquirement of a high order. The historic definition unquestionably provides for them.

g If the writer may modestly put forward a suggestion for a revision of the historic definition, he would word it: "The Engineer is he who by science and by art so adapts and applies the physical properties of matter and so controls and directs the forces which act through them as to serve the use and convenience of man, and to advance his economic and material welfare.

h It may be of interest to add that the accepted dictionaries of the day, the Century and Standard, define the engineer as one versed or skilled in the principles and practice of any department or branch of engineering, deriving the word from older forms which means he who makes or uses an engine. Engineering is further explained as the science and art of making, building, or using machines and engines; or of designing and constructing public works

or the like, requiring special knowledge of materials, machinery and the laws and principles of mechanics. Both give as a secondary meaning, one who runs or manages an engine. Both the French and the Germans avoid this latter double use of the word by calling the practitioner of this sort of engineering a *machiniste* or a *maschinist.* The French also have the word *mechanicien.* The dictionary phrases are a little hard on the mining engineer, for example, who is scarcely visible in the description.

i This leads up naturally to the differentiation of the mechanical engineer from those versed and skilled in other branches.

7 In making the following classification it is obvious that unanimity cannot be secured from all as respects the number of branches to be recognized. With this apology and for the purpose in hand there are at least thirteen:

a The mining engineer and his close ally the metallurgical engineer is concerned with the discovery and the winning and extraction from the earth of its buried treasures of oil, fuel and rock. He touches the geologist and mineralogist on one side of his functions, and the chemist upon the other. Midway he allies himself to the mechanical engineer for the power to overcome his resistances and to the electrical engineer for its convenient transmission to the working point. If he concentrates his ore after winning it from the earth he calls again for his machinery upon the mechanical engineer. His profession passes at one limit into the craft of the quarry man; and the other, he calls on the art of the civil engineer for his tunnels and for his shafts; or the tunneling and shaft work of the civil engineer is done for him by the miner. The metallurgical engineer who transforms the crude ore into marketable metal or into the merchant form or structural shape is allied to the chemist upon the one side for his processes and to the mechanical engineer upon the other for his machinery. The electrical engineer is more and more furnishing him the energy for conversion by heat through electrical channels, the mechanical engineer furnishing the latter his power. The mining engineer may be both miner and metallurgist. The iron and steel metallurgist is usually a mechanical engineer.

b The electrical engineer is primarily entrusted with the transformation of mechanical or chemical energy into elec-

tric form, and its transmission in that form to the point of use, where it will be again converted into some other shape. The electrical engineer has made his own the question of generating such electric energy for the solution of the problems of lighting, transportation of passengers by railway, and communication by telegraph and telephone. He touches the physicist in the realm outside his applications of science, and has the mechanical or hydraulic engineer next to him to supply mechanical energy to his generator, and the mechanical engineer beyond him, where his energy drives the tool, or operates the pump or the elevator. Where his energy is made to appear as high heat, he serves the metallurgist, the chemical engineer; where it appears as low heat or as light, he serves the individual members of the community directly, as he does in the problem of communicating speech. His field is very definite.

c The naval engineer and marine architect is a specialized mechanical and structural engineer. His hull is a truss unsymmetrically loaded and variably supported: his motive power a definite yet widely diversified problem. He covers in addition a wide range of special problems when his vessel is also a club house or hotel, on the one hand, or a powerful fighting machine upon the other.

d The military engineer must cover both the defensive and the offensive department of his avocation. On the one side he is a structural engineer, and the problems of effective transportation enter his field, which he therefore shares with what is usually called the civil engineer. On the side of attack, the problems of ordnance both for its construction and for its operation take him into the field of the mechanical engineer and electrical engineer, and his problems touch those of the physicist and the chemist and the mathematician on the research and theoretical side. In fact the problems of the military engineer are probably those in which the solutions offered by pure theory can be most directly utilized of any presented to the engineers, inasmuch as questions of cost and of financing are usually secondary for him. If the result is worth attaining at all, the national governments will always be among the most lavish spenders.

The Chemical Engineer is a new applicant at the door of

professional recognition in certain quarters. He is the engineer in charge of production or manufacture where the process or the product, or both are chiefly or entirely dependent upon the theories and practice of chemistry. He shares his field with the metallurgical engineer as respects the manufacture of metals; he is a mechanical engineer as soon as the plant becomes large enough to warrant the application of power and machinery to the mechanical handling of his product. Gas-plants, sugar and oil refineries and the straight chemical manufacturing corporations call for such a man, whatever his designation. It would appear, however, that the normal tendency of growth and development in this field will be toward the utilization of two types of man. The one will be the chemist and the scientist; the other will be the mechanical engineer and executive. It may easily happen that in the days of small things the two sets of duties may devolve upon one man; later on it will be found that the best qualifications for both duties will not be found in one individual, and the volume of duty becomes too great for one man to be effective in both. When separated, the cleavage will be along the above lines.

f The sanitary engineer is a specialist in hydraulic engineering in the applications of water supply and drainage as means to secure the well being of the community as respects its public health. His field expands from that of the wise precautions respecting the piping of the individual house, where he touches the craftsmanship of the plumber, up to the broadest problems of sewage disposal and utilization, and the healthful supply of potable water for cities, free from bacterial or inorganic pollution at its source or in transit. His co-workers are the bacteriologist and the physician. It would seem more serviceable however for the purpose in hand to group such men with what are hereafter to be called the civil engineers.

g The heating and ventilating engineers, making a specialty of the sanitary requirements of enclosed houses as respects their fresh and tempered air supply, are really sanitary engineers, having however an outlook and a relation to mechanical engineering in the appliances of their function rather than toward civil engineering.

h The refrigerating engineer is concerned with the trans-

formation of mechanical or heat energy so as to lower the amount of such intrinsic energy in any material or space. He is most unassailably a mechanical engineer.

i The hydraulic engineer is of two groups. The one type concerned with the problems of the river or canal for navigation or for power with the dam and its accompanying details of water ways and controlling gate houses and sluices; and with the gravity storage and distribution by mains of the city water supply has plainly his outlook toward civil engineering. The other type, concerned with the water motor and its attached machinery for its operation; with the mechanical handling of water for city use or for power in industry, the designer of pumps and hydraulic utilization machinery has his outlook equally definite upon the field of the mechanical engineer. The future is likely to see this differentiation emphasized, the one class calling himself a civil and hydraulic engineer, and the other class a mechanical and hydraulic engineer.

j The gas engineer has two sets of problems: The one is the intra-mural manufacture and storage of his product, where his functions are those of the chemical manufacturer, and he should be both chemical and mechanical engineer; the other is the distribution problem for whose solution is required the skill and knowledge of a type which is unnamed, but which logically in parallel with the hydraulic engineer above, should be called the pneumatic (or gas) engineer. Industry has never stopped to be logical however, and the pneumatic engineer should be a name to suppress. The future will doubtless widen the scope of the gas engineer to cover the plants which make and use fuel gas for power and heating in units not so large as those on the municipal scale now in evidence for lighting mainly. Such creators and engineers for heat and power will plainly belong in the mechanical field.

k There is no recognized group of engineers of transportation, or transportation engineers. Such a group obviously exists, however, whether or not the name is attached to an organization inclusive of all, or is in general use. Such are the engineers of motive power on the steam railways, with the master mechanics and the signal engineers and the operative class on locomotives; such are the

street railway engineers; the car builders; the maintenance-of-way engineers, the bridge engineers, the engineers of floating equipment. From the bottom of the rail upwards, these have their outlook on mechanical or electrical engineering; from the bottom of the rail downward, upon civil engineering.

8 The foregoing grouping does not claim to be exhaustive nor inclusive of all subdivisions of engineers even so far as it has gone. The current activities of the Engineering Building reveal bodies of municipal engineers, of illuminating engineers, of engineers concerned in fire protection, and many others. But the purpose has been to clear the way for the separation of the two most closely allied in function and service, the civil and the mechanical engineer. The civil engineer is confessedly differentiated from the electrical and from the mining engineer: he has been more and more utilizing the achievements of the mechanical engineer, or the latter has been invading the former field of the civil engineer.

9 It is plain that to the civil engineer belong as of right all problems relating to the canal, the lock, the river, the harbor, the dock, the sea-wall, the break-water, the highway, the aqueduct, the bridge, the viaduct, the retaining wall, the permanent way of the railway below the foot of the rail. He also has nearly the whole of the municipal problem in streets, sewage, distribution of water, the location of railways, with geodetic and other surveying are his. He has the foundation of structures in any event, but may have to share the roof and the skeleton steel frame with other specializations Tunneling is usually done by civil engineers, although it was originally a mining engineer's prerogative.

10 To the mechanical engineer on the other hand, belong as undoubtedly, and as of right the problems of the generation of power in power houses and power plants, and its transmission to the operative point unless this latter is done by electric means. It is a fair question, however, when the electrical engineer simply transmits energy generated by the mechanical engineer and utilized in industry by the latter after transmission, whether the electrical engineer as an engineer of transmission is not for the time a mechanical engineer. If the transmission were by compressed air on a sufficient scale, calling for a specialist in that field, would such a man be called a compressed-air engineer?

11 It is also plain that to the mechanical engineer belong all design, creation and manufacture of tools and machinery. This makes him therefore the natural administrator or executive of the

production processes involving the use of machinery in factories and mills, and it is here that he finds his broadest scope and widest opportunity, as will be further demonstrated hereafter. As creator of machinery he will be a draftsman or designer of a producing plant: as operator of the plant considered as a tool for production, he will be a general manager or superintendent, or will perform these functions as owner or as president, vice-president, agent, secretary or treasurer. As a producer of power, the railway will make the mechanical engineer their superintendent of motive power, and the rail and joint become also responsibilities of his; as administrator of men and machinery, he becomes master mechanic of the railway and more and more such engineers are chosen to be general superintendents. The automobile or motor vehicle engineer is of course a mechanical engineer. From his knowledge and special training he becomes the inspector and tester for all departments of mechanical production.

12 But this relation of engineer of production borne by the mechanical engineer is at the bottom of very notable developments of progress. As the scale of production increases with the aggregation of capital invested, the permanence of the business becomes inseparably bound up with the satisfactory quality of its output. Hence there grows a system of business in which the reputation of the producer becomes a factor compelling him to satisfy the buyer as respects the engineering excellence of his purchase; and it becomes possible for the contract between the two to be based upon the specifications created by the producer or seller, and not by the engineer of the buyer. This makes for cheapness and promptness of production and delivery, since standard articles become possible and frequent. It is a system lying largely at the base of the American success in competition in foreign markets, as it differentiates our practice from that of England for example. It points to a narrowing of the scope of the office of consulting practitioner as compared with the widening scope of the manufacturing engineer. It marks a broad differentiation between the civil and the mechanical engineer, in that the former never or very rarely attaches himself to a producing interest. He serves a municipality, a corporation or an individual always as a representative of their interests as a buyer or user. It is his function to see that specifications unfriendly in intent to the interests of the seller are carried out by the latter. The engineer of production is called on to originate his specifications and to enforce them in production, in order that the guarantee of quality and of economy in use may both be satisfactory to such user. The entire point of view of the two types is radically diverse.

13 This achievement of the manufacturing or production engineer

gives significance to the work of the considerable group of mechanical engineers, who have been earlier designated as "co-ordinators of design." These are they who take the satisfactory designs or creations of the producing engineer and combine such elements into a unit for some industrial purpose. It would be foolish and unwise for such men to pass by existing standards upon the market and create special designs of their own. These latter would not only be more costly to pay for, but their delivery would be slower, and problems of repair and replacement be many times more difficult, costly, and delaying. Their creative function as engineers however is different from that of the producing engineer proper; yet to succeed demands the same faculty of critical selection and of adaptation of means to ends upon a basis of sound science which distinguishes the other group. To them belong those engineers of operation and development of existing plants, who rarely create, but who skilfully select and adopt and combine.

14 This economic condition also has given rise to a group of engineers properly mechanical, who are directly and productively related to the producing corporations as their representatives in their selling organization over a large territory. It is unfortunate that these men of professional standing and of engineering qualification should be so often called "Sales Managers." It is their duty to act exactly as the co-ordinator of design does in his office, and secure for the intending purchaser an engineering solution for his needs which shall be satisfactory to him. His value to the producing corporation is inevitably measured by the number of contracts which he brings them: his value to his clients is measured by the engineering value of the specifications upon which such contract is based. The mere salesman could not perform the duty of the case, unless the buyer were protected by a consulting engineer. It is economically to be preferred as above, to have the specification emanate from the seller.

15 And finally, the group of engineers of production must include the industrial engineers who are organizers of men or departments or works as tools of production. These men are not creators of visible machines embodied in steel or iron, which perform material functions before our eyes. Yet are they creators of power and directors of forces under the fundamental definition. They may do this as independent consulting engineers from an office relation; or they may be continuously employed for this purpose by one producing concern. In either case their successful achievement is the same in principle and in result as that of him who devises a new automatic machine by which output is increased and cost of production cut down.

16 The final criterion or touch-stone for all these claims for the scope and function of the mechanical engineer must be the answer and attitude of the profession itself. The American Society of Mechanical Engineers exists to promote the Arts and Sciences connected with Engineering and Mechanical Construction. The member must be competent to take responsible charge of work in his branch of engineering as designer or constructor, or he must have served as a teacher of engineering. The Associate must be competent to take charge of engineering work or to coöperate with engineers. This brings in the journalist, the patent lawyer, the business man, the contractor. The junior must be either an engineering school graduate, or have had such experience as will enable him to fill a responsible subordinate position in engineering work. Candidates must be proposed by members of the Society, supposedly familiar with its functions and standards, and such proposers are called on to answer searching questions by the scrutinizing Membership Committee of five. The Committee on Membership reports recommendations of qualified persons to the Council of the Society, who again scrutinize the list, and it is finally submitted to the entire voting membership by letter ballot, with privilege of rejection by a limited number of adverse votes on any name. Hence it may be assumed that the membership contains only those whom the administration of the Society and its active membership regard as suitable members of a Society of Mechanical Engineers.

17 Who are these members, and what are they doing? The actual list of members enjoying the privilege of membership is increasing month by month, so that the figures for the autumn of 1907 are correct for only a few days. Taking the membership in the summer of 1907 as 3152 and neglecting the foreign or nonresident membership of 175 from the count and correcting the remainder for deaths, a total is used for the present purpose of 2957, in all grades The list has been then carefully scrutinized and classified as given in the published catalogue respecting avocations. The grouping for the purpose in hand has been into the following classes:

a The Unclassifiable: made up of members who have retired, or who are not in practice or whose record in the list is a mailing address only, and their sphere of activity unknown to the writer; these are 306. If the groupings were more nearly of a size, this number might hold a balance of preponderance which would disturb the later conclusion. As the matter stands however, the number is not a material factor, since in all they number only ten per cent.

b The army and navy engineer 11, and the marine engineer 18.

c The hydraulic engineer 12.

d The patent attorney, solicitor and expert 25. Doubtless many engineers grouped later under Office Practitioners are also engaged in this same department.

e The technical journalist, editor and contributor 30. These men have a wide familiarity with engineering matters and expert knowledge.

f The mining engineer and metallurgist 31. This includes the type following mechanical engineering at mines or at the metal producing plants other than steel works. These last have been called manufacturers.

g The contractor 48. He is a man who is a business man for the profit of the thing, but who makes his engineering knowledge, skill and experience contribute to his business. Such are the men who build great railway terminals and do their own engineering in connection with the undertaking.

h The testing and inspection engineer 49. He acts either for a producer, or as a consultant for the buyer.

i The operating engineer 55. He is the man to whom is entrusted a plant, to operate and bring results from it. He may be a creator, or he may make effective the creations of others. He is in charge of power houses, street railway systems, institutions, factories and the like. The sea going engineer and the railway engineer might be added to this class.

j The locomotive and railway engineer 57. This is the motive power man, the locomotive designer and builder, the railway shop superintendent and master mechanic and all others concerned in the power end of the railway business.

k The electrical engineer 65. These are the power plant experts, the street railway engineers who are not power plant men, and a few of the engineers connected with the great electrical producing companies. Most of the latter however from their position and duties will be included in the manufacturing class. That they are manufacturing electrical equipment is a mere accident of the present demand and they are not electricians so much as producers.

18 As respects many of the foregoing and their representation in this Society, it must be noted that great numbers will owe a primary allegiance to other bodies closely related to their specialty. Their

membership in this Society is an extra adherence for reasons of greater or less personal weight.

l The professor or teacher of engineering 185. This is a large group, probably larger than in any other similar body, and for the reason that through the Middle West the state college is very strong in its industrial and mechanical departments, and its officers desire touch with the work and personnel of the producing enterprises of the country. Comment or criticism by such users of the university product will be most helpful to the instructors of every grade.

m The draftsman and designer 115.

n The local manager, or district representative engineer of the manufacturer 153.

o The shop executive, superintendent, department manager, assistant superintendent in large works 338.

p The producer or manufacturer, owner of the plant, president, vice-president, or executive officer of the corporation, and the mechanical engineer of such producing bodies 966. The subdivision of the last four groups is for the purpose of showing the widespread significance of the contention of this paper as to the economic significance of the mechanical engineer; if all four were grouped into one, they would include 1572 or practically half of the total membership.

q The last group is the office practitioner or independent consulting engineer not officially or visibly related to a producing enterprise, 493. This includes doubtless many who might have been included in one of the other classes previous to Class *l*. It covers the coördinators of design, who are often also contractors, probably many patent men, hydraulic engineers and local managing experts, which if placed under the other headings would still further reduce the size of this class. The broadened scope and opportunity for doing great work which are presented by the large aggregations of capital in the producing enterprises, as compared with the difficulty of great engineering achievement with little capital, are continually attracting men from this group into Class *n*, *o*, and *p*.

r Presenting these facts in tabular summary:

Group Name	Numbers		Percentage	
a The unclassified	306		10.3	
b The army and navy	11		0.4	
and marine	18		0.6	
c The hydraulic	12		0.4	
d Patents	25		0.8	
e Journalists	30		1.0	
f Mining and metallurgy	31		1.0	
g Engineering contractor	48		1.6	
h Testing and inspecting	49		1.6	
i Operating engineer	55		1.8	
j Locomotive and railway	57		1.9	
k Electrical engineer	65		2.2	
l Professor and teacher	185		6.3	
m Draftsman and designer	115		4.0	
n Local manager	153		5.2	
o Shop executive	338	1572	11.8	53.6
p The manufacturer	966		32.6	
q Office practitioner	493		16.5	
Total	2957		100.0	

19 There would seem therefore a good ground for defending a twentieth century Tredgold who should define or describe the mechanical engineer of his period: "The Mechanical Engineer is one who by science and by art so adapts and applies the physical properties of matter and so controls the forces which act through them as to serve the use and convenience of man and to advance his economic and material welfare. He does this mainly by storing and liberating motor energy through machines and apparatus which he designs and installs and operates for the purpose of fostering and developing the processes of industrial production which use and require such power upon a large scale."

20 The foregoing discussion draws after it as in its wake a group of other interesting questions; or to change the figure, a number of open doors to other topics appear as we follow the guide along the corridor. Among these for example, is the historical one, as to how the engineer came to be the central figure which he is to day. In the earliest times the patriarch with knowledge of safe and desirable pasturage for the flocks was the central figure; later, the war-lord was king; he in turn gave way to monkish priest as supreme center, and after a recrudescence of the warrior and conqueror we are now planning armament and training men and scheming policies to secure peace which shall enable the production engineer to do his best work and with the least waste. As early as the legend of King Solomon is the claim of the tool maker, and the mechanical engineer of today is the

heir of the functions of the tool maker on the largest scale. Again, the educational significance of the definition is most important. We have derived our standards in the technical schools from the requirements of the historic Military Academy at West Point. This in turn inherited the policies and practice of the European governmental schools for engineers. We have borrowed also from France and Germany directly. Very close to the heart of such standards lies the devotion to the highest mathematics both as a discipline for the mind and character as a preliminary training for study in statics and dynamics, and as a means of separating the qualified and the assiduous from the incompetent and lazy. But of fifty per cent or more of the graduates are going to find their life work along lines which make no call for extended use of the higher mathematics; if by using, as the separating sieve a device which lets through many men of a mentality ill adjusted to the demands of practical life in production, and which holds back many men who lack facility in working with symbols of quantity because they can better handle the larger problems of the quantities themselves, then it is a fair question whether the splendid discipline of high mathematics has not been bought at too high a price. Could we not get a better prepared man for his life work if the same discipline and the same selective process for the fit had been secured by more and better physics and more and better chemistry and more economies, even if these were bought at the price of some mathematics?

21 But my time and the occasion demand that we pass at once to the second phase of the thought of the evening. What can or may the Engineering Society made up of Mechanical Engineers as above, do for the profession? What are its duties and functions? It is plain that these are in two directions; its service to the members within it, its duty to those outside of it. Some duties and service will be the same to those within and without, in others there will be differences.

22 Taking up first the service to the members within it, the Society can do at least eight things:

First it serves by its existence. The fact that there is such a body at all is a token of its strength. For it means that there are three thousand men and over, who with all their diversities have yet a common dependence upon law and principle, and who are pursuing a common aim. The courage and cheer which comes from association and comradeship is a service. The wave which buffets and all but overturns the struggling skiff beats fruitlessly for harm against the tonnage of the ocean liner. Steadily the great aggregation plows

her way through stresses which would be fatal to the same totals if subdivided into units. The whole has a strength which is even greater than the sum of the strength of all its parts.

23 This benefit may be regarded as one of the most widespread that the Society offers. It is independent of residence location and is reaped by the foreign member as well as by the dweller near the centers. In fact it is more significant to the lonely dweller than to the metropolitan member. It remains even when the other returns to the subscriber to the Society in publications, in association and in meetings either lessen or cease. He may well keep on paying dues (perhaps reduced in amount) after the value of papers and meetings become no longer worth while.

24 The value of this return is greater in proportion as the Society is larger, so long as its quality is maintained. This is the argument for the national and international body as contrasted with the local body or section. Any policy or step which gives occasion rightly to charge a tendency for a national body to localize is an invasion of opportunity and value. The local body may offer some advantages of its own. It does not offer this one. A localizing of an office organization or of a printing contract or even of a library is not a localizing of the Society as a whole. This happens when it narrows its outlook over the professional horizon or its spheres of influence. But the remotest and least considerable member profits more from the existence of the Society in this respect than the recognized leader or the man of acknowledged eminence.

25 A second function or service of the Society is the offering of the right of association. By this is meant more than the opportunity of social intercourse at meetings to be referred to later, but the privilege of association in the larger sense. It is a great thing for a man to feel that his name appears upon a list which has been signalized by the names of John Ericsson and Chas. H. Haswell, and still bears those of John Fritz, Rear-Admiral Melville, Thomas Edison and Chas. T. Porter, John E. Sweet and George Westinghouse. Such association makes for a sense of distinction and of pride which is in itself a safeguard like the ancient obligation "*Noblesse oblige*." Can any nobler human ideal be set before a body of men associated together than that it should occur to a man when tempted to lower the standard of professional or business ethics to draw himself up proudly and say "My dear Sir, I absolutely decline. There are certain things no member of the American Society does." To do dishonorably is to bring shame and confusion upon all his class and disgrace his associates upon the same roll.

26 Further than this, by reason of this association, the triumph and achievement of one is the glory of all, "This advance in science, in art, in production, in management was made by my colleague and fellow member." This also stimulates the individual to do his own share beyond the confines of his narrower or purely personal interest, inasmuch as he is bound by an *esprit de corps* to confer benefits upon his associates similar to those which he has himself received.

27 And again the member of the Society is privileged by his association to feel that in cities which are strange to him he has yet the right of fellowship with other members there so far as the right may be wisely exercised. The business approach is easier; the road to acquaintance on casual meeting is shorter where both parties recognize the standing of their common membership. All these emphasize however but the more strongly the necessity for safeguarding the quality of the membership, by the proper committee, by the Council and by the voting members, lest abuse of this so great a privilege make it necessary that the best members should withdraw it.

28 The third function of the Society is that of furnishing the advantages of a body corporate in the profession. These advantages appear both among the common-places of the legal aspect, and also from a general view point. The Society becomes a continuing and permanent body whose policy is unaffected by individual deaths or removals. Hence it may safely be made a custodian and trustee of significant gifts. This very building in which this meeting is convened belongs to the Society and not to individuals. It is the Society who has furnished or is to furnish one third of the ground on which it stands. It is the Society which has furnished the brains and the assiduity whose results appear in the details of its arrangement. If there had been no Society there would have been no building, in whose splendor and distinction each individual is entitled to feel a share. The Society may therefore be made a legatee and beneficiary in wills and testamentary gifts. It can be entrusted with historical material which is so apt to dissipate in the hands of individual inheritors.

29 But in the larger and general sense the Society supplies a corporate unity, in that as an organization things come to it which would not be given to individuals. Nowhere is this more evident than in invitations to visit works or places which would not be opened otherwise, which has happened again and again in the past. The Society as an organization supplies the avenue of approach and contact when a body such as a governmental department desires an action which shall be general, and not that of a few persons. This fact of corporate action calls for emphasis of a principle sometimes difficult to carry

out except with the good-will of all. It is that when the Society is the recipient of special courtesies and invitations which would not be the privilege of all individuals, it calls for withholding of these privileges from those who are not members, but who are present at any time or place as invited guests accompanying members. It will be plain upon a moment's reflection that such persons should refrain from causing embarrassment by their unintended presence.

30 A fourth function of the Society is that of providing meetings of its members at proper intervals during the year. An ideal meeting would be one in which at least three elements were combined in wise proportions. The first is a mental stimulus in the form of live topics of professional interest presented as papers or otherwise; the second is the opportunity for social or intellectual attrition with other minds and temperaments during an association or intercourse lasting long enough for acquaintance to ripen; the third is a mental and physical stimulus and relaxation of tension by a sight-seeing which shall not be interesting only for the empty minded or the uninformed. Danger lies in any excess or undue lack of these several elements. If there are too many papers or too much time is given to their discussion, the meeting becomes a weariness from excess of the mental stress, It was a very good friend and shrewd observer of experience who cautioned the writer in an early day: "An audience has a distinctly marked elastic limit of patience like a piece of steel. Strain that attention beyond its elastic limit, and it takes a permanent set; it will hate you and despise your best works."

31 On the other hand, to have too few papers or on topics of little value and interest, is to make a failure for the earnest and busy man who has a work to do at home and is "straitened until it be accomplished." The Society wants his presence and approving attitude of mind for the good he can do by being there; if he feels it not worth his while to come because the meeting is but a frivolity and undeserving of a serious man's attention, both presence and approval are lost. There must be a serious nucleus, else the meeting is a mere excursion. Too great an intellectual appeal, made at the expense of the opportunity for meeting other engineers for conference, for exchange of experience, for story telling, is to invite the member to stay at home and read the printed papers there at his own hearth. If he loses or must lose the vivifying and rousing effect of the spoken word and the electric snap of meeting mind to mind, why not stay away? Particularly as a man grows older and reaches the plateau of middle life, the advantage to him of the renewal of old acquaintance—to which he clings more and more as his circle narrows—becomes greater and greater. It is a safe-

guard against a stiffening and stagnation. In this view the practice of the Society in registering and even in labeling all members in attendance at a convention is not a whim or a fad. It arises from a definite desire and purpose to make the approach of unacquainted members both safe and sure and short in time required to effect it. We cannot all remember names; to remember faces is for some a considerable effort. The time of a convention is too short to waste any of it in indirect or preliminary effort to know a man. Introduce yourself by emblem and by name, and enrich your memory of the meeting by what the other fellows thought and said. No home reading of the best papers will result in this.

30 The third element or factor in a Society meeting is the sight-seeing. This must be a lure or bait, since the first or intellectual phase is partly attainable at home, and few men are brave enough to confess to the existence of the second factor. But the sight-seeing must have a professional or intellectual content or nucleus, or it will not appeal. It must be the opportunity to see or study new development upon its own ground, or it must give a man a chance to examine a variant upon his own line of work, or by reason of its extent and magnitude or the brains or talent expended on its execution it must at least appear to be worth seeing. Otherwise as before the serious minded and the earnest are not attracted by it. These meetings do not occur in vacation time, they are in the midst of the serious business of the year. A meeting some years ago where the Society went to the sea shore and away from all engineering opportunity, while a memorable one professionally, was yet in the retrospect a terror to use by night against the misdeeds of naughty children. On the other hand, the things the member carries away in his memory are not the papers nor discussions. The pleasures lasting in his recollection attach to the things he saw and noted and the people he met. To repeat the shrewd comment of a gifted member who had been chairman of the local committee, and who was being complimented on the successful visit to a steel works of his city: "The meetings of the Society are like a brick wall. The papers over which the Secretary labors so strenuously are the bricks, but these trips and their opportunities are the cement which makes the bricks a unit." Too few bricks, a poor wall; too little cement or badly chosen are equal failure.

31 This discussion of the function of the meetings gives opportunity to record some personal convictions. In a Society which is national in scope and membership, the selection of the places of meeting should have some regard to the center of gravity of the

membership, as it asserts itself territorially. The alternate swing of meetings from the Atlantic slope to the Mississippi Valley has much to commend it; but the extreme is reached or passed when the meeting is so held that both the length of the railway journey and the consequent absence from their posts permits only a wealthy and leisured few to get away to attend it. In other words, the excursion or sight seeing end here overbalances the other features of such a meeting, and many cannot afford it. In this same category is the propositon to hold a meeting for papers and discussion as a feature of an excursion or during its progress. The two elements do not mix; the excursion is spoiled for those who must bear the burden of the session; the session is spoiled because the most desired participants are not there. The only excuse will be when the excursion is so long or so tedious as to be a failure as an excursion—when it ought not to have taken place at all.

32 The speaker has never been a partisan of the formal banquet as a feature of a Society meeting. Unless the Swedish custom prevails of changing seats at the tables, any one meets only those near whom he is seated. Breadth of association or contact is prevented and when fortunate to be among a group of friends, no advances of others are likely; and if among strangers or the uncongenial, few experiences are more dreary. The number of notable dinner speakers among a group of engineers who are earnest devotees of work is small in any case, and most of these are not likely to be present. Dull or futile dinner speech is unendurable. If the dinner is costly enough to be worth while in itself, there is barred out from it a considerable number of men who must regard the expense in planning to attend the convention at all. Shall the ladies present at the meeting be included or not? If included they blank one side of each member so accompanied, and smoking will not be general. Hence, it has always seemed that another form of public social function was much more worth while than the banquet was likely to be; and was very much less trouble to arrange for.

33 The presence of the ladies at the meetings of the Society has been invited and encouraged from the very beginning, not only as a means of pleasure to themselves and those who bring them, but because they had a distinct function in making the meetings successful. The woman in America as elsewhere is the social expert; the busy or lazy man farms out to her the doing of many social duties, in whose absence the community would lapse in manners and culture. Hence her presence and her activities at a meeting tend to raise the tone much above that which would prevail in a purely "stag" reunion.

The man exerts himself in directions of social effort as he would not do in her absence. Her presence also is a restraint, and prevents things from happening which might occur if the man was alone. She secures for the man an access and an ease which without her he would lack. Doubtless also the woman acts to persuade the busy member to bring his participation to the meeting, when lacking her influence the pressure of business would be allowed to keep him at home. His presence and experience cannot contribute to the meeting unless he is there.

34 The meetings of the Society are one of its principal opportunities whereby the Society as such reaches and impresses the general public in the cities where it meets. The professional sessions do not wield a very great influence in this respect; but the other features of the meeting do. Hence it has been felt to be of the first importance that in all its outward relations the professional and scientific sides of its purpose should be strongly emphasized, rather than its contact with commercial problems. To this end, the prohibition of advertising or publicity procedure in its headquarters has always been enforced, and so far as possible also in the hotel corridors and foyer. If the commerial instinct for business were once allowed a foothold, the meetings would become the arena of industrial and commercial rivalry, and their high character would disappear. At the meetings also, where the membership comes together on the social plane, the Society is rather comparable to a club, than to a purely impersonal professional body. It offers therefore the club opportunity for discussing business or personal interests and ambitions concerning purchase and sale, which are entirely legitimate if not abused. If the members do not desire immunity from interested partisans of any specialty, the Society can not secure it for them. It may discourage only the making of it inevitable.

35 The view of the Society as a club during its meetings justifies it in exercising the right to protect itself from an undesirable member who would there bring it into disrepute by habits or behavior in which the majority cannot uphold or defend him. It may not be the primary business of a Membership Committee entrusted with the consideration of a man's professional fitness for membership to reject him if he is so addicted to the use of intoxicants or other drugs as to be likely to bring discredit on the Society at a meeting; the membership however will surely defend such a Committee when it seeks to protect the fair fame of the body as a whole. This must be the explanation of the policy of not admitting to membership candidates who belong to a race with which the Caucasian does not socially assimilate.

The man may be all right professionally but his admission would be contrary to good policy. The Society has also the same right to protect itself against any who are known to be prone to unprofessional conduct of any kind. It must do so if the function and privilege of association earlier discussed is to have any meaning.

36 This division of the subject would not be complete without a treatment of the question of local meetings of sections of the Society. Such sections may be either territorially grouped, or by topics and common interests. As provided for in the By-Laws and Rules of this Society they are to consist of elected members only as regular members of the Section, non members having only the guests' privilege of participation in papers and discussions. Members of sections therefore derive their advantage from the existence of the national body and from association with its members independent of the local section, and the advantages of the publications, hereafter to be referred to, from the same fact as well as the general meeting privileges. What they derive in addition is the privilege of meeting other members at shorter intervals, and without entailing expense for a journey or a difficult absence from home. But the very frequency of the meeting and the ease and absence of sacrifice by which it is secured make for a lessened interest in such meetings after the first novelty has worn off and the acquaintances have been formed. The novelty of the more infrequent general meeting is lacking, every one becomes tired of hearing the old "stand by's" at every meeting; the supply of local material for discussion dries up, and what comes from the office of the national body does not happen to stimulate. Then the section becomes a social body only, and does not help the national body particularly, if it does it no harm. It would be much more useful if what is sought by the section or local chapter were sought in another way, or by means of a body made up of both members and non-members, acting in some affiliated relation with the national body, whose discussion properly therefore falls into the final part of this paper.

37 In the fifth place, so long as the members, Council and Membership Committee are sensitive to the duty respecting the quality of the applicants for membership, it will follow that the fact of membership in the Society is a stamp of quality of engineering achievement—a seal or *cachet* of reliability and professional standing. Three or five men proposed this man, and answered most searching questions as to his performance and eligibility. A membership committee of five experienced scrutineers, canvassed the application and the replies of the backers, and perhaps went outside to establish the candidate's

claims or to force the proposers to effective defense of them. Then the Council criticized the report of the committee and ordered the man's name to ballot; and finally among all who voted on his name there were not found two per cent who knew anything against him which would justify his rejection. All human judgment is fallible, of course; but the successful passage of such an ordeal is a strong favorable presumption as respects any man, to say the least.

38 Now this stamp of approval upon every enrolled member is a very precious possession. The key to admit to it is held by the voting membership, and those who propose candidates. The membership committee unlock as it were an outer door to the vault, but they do no more than this. They do not admit to its privileges. Hence the reciprocal duty of the members is made very plain; if the Society has a function or service along this line, the individual voter is obliged to the greater scrupulousness in the exercise of his duty. If anybody can get into the American Society then membership in it will be little prized. If this separation of the members of the profession into the class within the Society and the class without it be objected to as anti-social, aristocratic and undemocratic, the reply would be that so also is the family. Any man can get into the Society who has shown himself to be qualified to do so. His objection must be against his lack of qualification and not against the Society which upholds a standard.

39 The sixth function of the Society is its creation and maintenance of a Library. It was not so long ago that every professional man had his private library of some extent, containing the books and periodicals he specially valued and used. But in recent times the enormous increase in the number of books required for any library with a pretense to completeness; the necessity for rapid expansion if it was to keep pace with the progress of the day, the investment required in society memberships to secure their publications, and the bulk of the current periodical literature of the profession have all combined to bring about a change. The housing and the care of a worthy private library became a problem practically insoluble for the individual, either in office or in home. Hence the opportunity arose for the Society Library, doing for all the members what each could do for himself only with the greatest difficulty or prohibitive expense. To reduce the unnecessary duplication of books and transactions and periodicals required only for occasional reference is a measure of evident economy and advantage..

40 A reference library which is not also a circulating library can only be made really serviceable to members who live near enough to the

library shelves to enable book and reader to be brought together at the home of the book. It is one of the problems of the immediate future to develop the circulating function of duplicate books and publications in a practical way, which shall protect the interests of all parties, enabling the library to render the largest net service. It would seem both narrow and unwise to lock up the library from the reach and use of those not fully qualified for membership, or not able to become such for other reasons. The Society therefore permits and invites a public use of its collections in addition to the proprietary use by the members. If such public use transcends the private use, then to impoverish the shelves by circulation without duplicates seems too heavy a price to pay. It should be noted that the coming together of the libraries of the three societies named as Founders of the Engineering Building has not only more than trebled the scope and extent of the library for all users, but has opened up the circulating possibility by bringing an increased volume of duplicates together.

41 The library also offers the possibility through its staff, of having researches made for members at a distance, and extracts made and sent, which could not be done in a public library, but which is normal and appropriate in one belonging to the member as of society right. The library can also be made custodian and legatee for books of value and usefulness when their former owner has no longer occasion or convenience to control them himself and give them room and care.

42 The foregoing services rendered by the Society to its members are all in an imponderable class, and do not have a value which is appraisable in legal tender. The non-member cannot buy them, however wealthy he may be. This makes them therefore of all the functions of the Society the six which are the most to be prized. They are like a franchise, in that the benefits which flow from them are not common to all members of the community but are conferred by special act of the corporate body. There comes next a function and benefit which is extended to members of the Society, but which differs from its predecessors in that it has also a material or appraisable cash value and that it may be secured also by non-members for a price. It is the privilege of the publications of the Society. It must not be inferred from the fact that this return to the members is put seventh upon the list that it is therefore an inconsiderable or secondary feature. It is on the contrary one of the most significant and important, and one around which are grouped many of the activities and much of the organization of the Society's business office. It is the item for which directly and indirectly it makes its largest expenditure; it is the element which conditions very largely the esteem in which the Society

will be held by members within and observers without. On the other hand, the putting of six other elements of Society worth and function before it, is intended as an attack upon an erroneous opinion held by some who have never had it attacked, that the publications of the Society are the only or the principal return to them for their dues and continued membership. When the volume or value to them of the Society's annual output of papers and discussions fall off in their opinion in any year, this is an adequate reason for discontinuing their membership. The existence and value of the preceding factors first enumerated should be sufficient rejoinder in themselves.

43 The publications of the Society come to the membership in three forms. The first is the monthly magazine or bulletin which is designated Proceedings, and distributes papers to be read at a future meeting, discussions on papers current or past, memorial monographs, book-lists and Society notices and circular literature. These replace the "Advance Papers" of the former day, and so far as possible incorporate the individual and separate circulars which used to be issued. Some of the matter in this magazine is not to be of permanent record, but of present and current interest. The second form is the bound volume of papers and appended discussions with index and consecutive paging, intended to be the permanent record for future reference. This must issue of course after the regular meetings and at an interval sufficient for the execution of all editorial work required. It need not contain all that the Proceedings did by reason of the limitations of bulk and the inexpediency of permanently preserving everything that every one said in all discussions. But this book, known as Transactions is the monument of the year's professional work. The third form is the pamphlets "Reprints" from the volume of Transactions, being the excerpts therefrom which contain an individual paper and its discussion, printed from the same type as used in the volume. These are of use when single copies of one paper are desired for any purpose, and a stock of them is kept on hand to meet calls from the future.

44 The publications at present include only material originating in the membership for presentation at meetings, and the result of the activities of the Meetings Committee in persuading contributions from members and others upon topics which they suggest. It has been felt for some time that these were unnecessary and undesirable limitations to place upon the possibilities of usefulness of the publications. They would be of incalculably greater value and use if they could be made to include abstracts of papers before other professional societies than our own; reviews of contributions to technical journalism,

book reviews and contributed material by non members on current achievements, new work, and live topics. An index of professional literature in society proceedings and other journals would be of the greatest value. In fact there does not seem to be any reason outside of the cost of making it so, why the publications of the Society should not be placed upon such a plane of value and usefulness that no engineer within or without the Society could afford not to regard them as a cherished possession and a valuable asset. Here however, also, as in the case of the value of *cachet* of membership, it is the willingness of the member to give of his time and service to the writing of papers and to the contributing to the material for the publication work of the Society which must be the great factor of success.

45 The eighth and final function of the Society is that which it contributes through the personnel and organization of the official staff of such a body. The Secretary is the natural and proper head of the Society office with such help in the editorial, the correspondence, the accounting and the clerical detail of the work as the size of the Society and the volume of its daily business make necessary. The conduct of the Society is a business and of no inconsiderable magnitude. The office is also most directly concerned in carrying on the detail directed by the working standing committees and under the Council. The degree and quality of the organization of the Secretary's office for its functions is the measure of its usefulness and service. The American Society of Mechanical Engineers may well feel proud that by the unselfish and self sacrificing devotion of a special committee in which a past president of the Society, an expert in such matters, was the leading spirit, the organization of its office is as nearly a model of such an undertaking as brains and good will can make it.

46 Such an office discharges functions to the membership at large and as a whole, and also to individuals. Perhaps the most important duty of the first class is the preparation of the semi-annual lists of members and its issue. This is not only a professional directory of the highest order, enabling members to know what each other is doing, specialization; but it is a channel for intercommunication whereby any member may feel sure of reaching directly the other members if he so desires. Its correctness and its completeness are therefore the factors of its value. This explains the trouble taken twice a year to ask the members about their address and their professional engagement. The Secretary's office also reaches every member for service in the matter of the candidates for membership, the voting functions of the members and the details of the meetings as they are to occur.

47 Besides these public or universal functions rendered to all

enrolled members the Society office may be compared to a ganglionic center through which the mentality of its management becomes converted into activity. Without the organization there would be no organ through which the Board of Directors or Council of the Society could exercise their functions as Trustees. The existence of elective office in the Society is made necessary by existence of administrative functions to be exercised. If there were no business there need be no President nor Vice-President, nor Managers to constitute the Council, nor need of choosing such from among those whom the profession is glad to know. If a distinction attaches to membership in the Society among the ranks as a private, how much more impressive the *cachet* given to the chosen officers. It is safe to say that office will never reach any save those who are without a blemish; to be entrusted with it an honor to be coveted, to be worn modestly, to be safeguarded jealously from harm or injury by error or misdeed on the part of its wearer.

48 The office staff renders also individual service as a medium of exchange of knowlege of men and of opportunity. Lines of communication and of acquaintance radiate from it as a center to the remotest bounds of the membership. Along these lines may flow question and answer, problem and information, need and its supply. Much of the Secretary's correspondence is of this class, which does not fall into the channels of routine business and automatic office machinery. The office is also the channel through which from without the stores of influence and capacity within the membership may be reached for the rendering of civic or national service either by the Society as a whole or its individual members in particular, on commissions on committees and in other important ways. In addition to these of course are the unclassifiable services which are personal and individual.

49 Is the privilege of service and of function all on one side, or has the Society the right to ask from its members a reciprocal duty to itself? The latter, no doubt. It is the duty of the individual member and his privilege to make at least the following effort:

a That no fancied advancement of his personal interests by a member should lead to any act or practice which will stain his character and injure his fair fame. If membership and its asssociation carries distinction when its members are distinguished, so the same force carries disgrace to all with the disgrace of the individual. It is for this reason that the Society for its own protection must have a means of ridding itself of a source of defilement through the unprofessional behavior of any.

b The individual member should seek to build up the Society in professional and numerical strength. The quality must be kept up for the sake of the elements advanced early in the argument, but influence goes with numbers of the right sort, and opportunity for wider service follows with the increased income on the one hand, and from increased scope of interests on the other. The Society has barely begun to draw from the great reservoirs of professional activity throughout the busy industrial centers of the United States; the world is ours also.

c The individual member should build up the activities of the Society as respects its papers and discussions. This calls both for personal effort in contributing himself from his own experience and work, and for the interesting of his neighbor also to do the same thing. If the dream of making our published Proceedings and Transactions a professional necessity to every engineer is ever to be fully realized, it must be when from all over the flow of knowledge, data, skill and experience into the Society's channels is deep, full and never failing. What it will mean to the Society if these ideals are made realities, it is beyond the clearest and most hopeful vision to pierce and prophesy.

50 Consideration must now pass to the final topic under review, which is the possible function of the Society to the profession who are not enrolled in its membership. If the foregoing argument has been conclusive, it is plain that such service or functions should be discharged without a prejudice to the interests of the membership itself. There are two extremes of view and opinion. The one is the aristocratic idea, that the Society exists exclusively for the advantage of the members. This in a modified form may be called the English idea, and is natural where passage from class to class is not easy by reason of their quite definite stratification. This plan would have the privilege of membership narrowly restricted, open only to proved and distinguished ability, and therefore to somewhat advanced years in the majority of cases. The other extreme is the communistic view professionally, that all adherents or practitioners of engineering are equally eligible, regardless of professional achievement or training. All draw equally from the common fund of professional advantage from membership; but of course there are no private fortunes of distinguished advantage, and no one draws as much in the larger community from an equal fund as he does in the former case. This again in a modified

form from the extreme may be called the German idea. The American does not fancy either extreme; but between them is room for a large diversity in the middle space. It was proposed in this Society (1889–1890) to create such an aristocracy. It has been urged (1902–1904) to so multiply the feature of sections of the Society as to approach to the more communistic or continental idea. The safe course is between these extremes. In the British aristocratic atmosphere, membership in the Institution carries with it a distinction which is recognizable; the advantages of membership in the German Verein of Engineers are on quite a different plane. Is a policy or plan possible which shall secure the advantages of both? The writer believes it is.

51 A membership which is ill-assorted and non-homogeneous will not be a strong one regarded as a unit. The differences in education, in extent and quality of experience in culture and social equality as the former factors affect this, would seriously interfere with the success and unity of the meetings. Unwieldy size of meetings restricts the number of cities available for such meetings, and shuts out many places altogether for lack of hotel and housing accommodations. To extend therefore the privileges of the first five functions of Association of one to its existence, to the inferring of distinction, of meetings and of corporate unity either cannot be brought about at all to those not eligible under the present wise standards, or else would become theirs at a price so great by reason of the debasement of the coinage in which their value is reckoned, that it ought to be paid. No such restriction holds however with respect to local meetings which may include members, to the library, to the publications and to the office organization of the Society.

52 The extending of the library function has already been referred to, when it was made a free public reference library. It is now open to free consultation by non-members as well as by members, the only present difference being that members are permitted access to shelves and alcoves directly, while others must work through the librarian and his staff in a general reading room. As the library grows in usefulness and in the members who use it, it will doubtless happen that the system of management will have to become identical for both groups, and the non-members' privileges be the same as those of the member. The same conditions—mainly financial—which will permit the addition of the circulating feature of the books among members, will also permit a similar although perhaps a more restricted circulation among the engineering public who are not members. This usefulness therefore would seem to be provided for.

53 The usefulness of the office organization under its present completeness and elasticity would seem to be limitable only by the demand, made upon it, the room for its accommodation, and the cost of its compensation. If extensions of its functions are accompanied with a proportionate return in income, the possibilities of this function would seem to be provided for as widely as use can be found for it.

54 The publications of the Society are available to non-members by subscription and by purchase. The cost of composition, illustration and editorial revision is incurred for the first copy of any paper, and all contracts and systematization are provided for the first paper secured and issued. After that it is merely the paper, press-work and distribution expenses which have to be met, which are the least in amount and vary directly or in a diminishing ratio with the number of copies made. Hence all that is necessary here is to create the demand by making the Proceedings and Transactions so valuable and so comprehensive that no member of the profession, member or non-member, can afford to be without them on his desk or in his reference library; and the result is won. This also would seem a result and a function for which all preliminary steps had already been taken. What remains is to do it.

55 This leads up to the final functions of the Society, with the urging of which this paper will have accomplished its ultimate purpose. It is that the Society should foster and cause the growth of other organizations or societies or clubs, specialized either by their location in city or district or state, or by their particular line of study and pursuits. Such bodies should be entirely autonomous as respects their officers and procedure and rules and financial support. Their membership should include both members of this Society and other engineers, the latter embracing both those who are eligible to membership in this Society, but having a prior allegiance to some other Society or do not as yet want to join any and those who by training or experience are not yet eligible to any existing national society. Such bodies should be known as: "The ——— Society of Engineers," or some equivalent name, the blank being filled by the name of the place where they prefer to meet, and the full designation to be "The ——— Society of Engineers Affiliated with The American Society of Mechanical Engineers." The emphasis is to lie upon the fact and relation implied under the word "Affiliated." The members of the local or specialized body would not be members of The American Society and would not or should not call themselves so. They are members of their own society. Their autonomy and self support secures for them the dignity and responsibility attaching to their own

control. Their errors of judgment or policy would not complicate the national body nor introduce political problems into the latter of a sectimal or factimal sort. They are and would continue to be local societies, or national ones with a specialized outlook. Now what will be the basis of the word "Affiliated"?

56 The American Society of Mechanical Engineers shall covenant to supply every member of such affiliated body each month with a copy of its monthly magazine containing its Proceedings, and such additional copies as can be advantageously used either free, or much below cost, according to the size of the local body. The papers and discussions in these Proceedings shall be the topics of discussion at such meetings of the local and special body as may be held, but by no means to the exclusion of papers on topics originating in the local membership which will be welcomed in addition. The American Society of Mechanical Engineers shall furnish or pay for a stenographer to report and typewrite the papers and discussions of the local meeting, and shall pay in whole or in part for the rental of the hall in which such professional papers and discussions shall be presented. In return for this, the local shall send a full typewriten report of its professional sessions to the Secretary of The American Society, which latter shall submit these to the Meetings and Publication Committees of the national body, with a view to the exercise of their right to publish in the Proceedings and Transactions such contributions as are judged of value. If the local desires to publish for itself material not available for the use of the larger body, it could do so through the advantageous large printing contracts and the editorial staff of the large body at much less expense to itself than if it tried to do the same thing by itself.

57 Among the arguments for this plan are:

For The American Society of Mechanical Engineers;

a A greatly increased scope of usefulness and influence, extending far beyond the limits of its enrolled membership, and limited only by the horizon of interest in the undertaking.

b The creation and multiplication of sources and centers from which material will be procurable to enrich its publications.

c Thereby a greatly increased value and demand for these publications: from the increased demand an increased income, and attendant increase in the value of the publications in a continuing ratio.

d An increased appreciation of the Society and its work,

leading to an extended desire on the part of those eligible to join the national body, enhancing for the latter the significance of the first series of its functions referred to in this paper which increase with the character and number of the members.

e The American Society attains these objects without lowering the professional standard of membership, without admitting even to *quasi* or implied membership persons who are not eligible through the regular channels. It avoids any financial or other obligation for the local, as would be the case if the latter were called a chapter or section of the larger body. It pays only for what is of value to it, which is the supply of professional literature; and where the local held no meetings nor sent any papers there would be no expense. The price which The American Society would pay is the increased cost of its operating account and publications, but this would seem likely to be more than returned to it, if not in cash directly, yet in other values. Probably also in cash.

58 For the local or specialized body would be secured:

a The prestige of affiliation with the larger body; doubtless therewith certain privileges of courtesy for the members of the local when a convention was in their vicinity, and certainly the courtesies of the building in New York city for such affiliates.

b A wide, certain, and cheap supply of invaluable professional literature, topics for their meetings when their own supply failed.

c The reduction of unavoidable expenses attaching to a local meeting for papers and discussion to a mimimum even to nothing if so desired. This value for the minimum would probably not be desired by most locals, but the dues prevailing in that local would be small and would be mainly devotable to their own interests.

d The maintenance of the standard in the local to a plane of creditable achievement. The continuance of the local could be conditioned upon an earnestness of devotion to it which should be worth while.

e The local would be entirely self-governing, with its own officers and control in every respect. Its own officers would command the dignity which alone makes the burden of office worth while, and the local is responsible itself alone

for its success or failure by reason of the effort put forth by those interested.

j The local by operating its business detail through the office of the national society obtains the pecuniary advantage of the larger scale of business in The American Society and the service and coöperation of its trained experts. Their accounting and purchases, as well as their printing, could be done for them at much better advantage in the large office. If accounting and addressing of envelopes and circulars were done at The American Society office, the office expense of the local would disappear, and the cost of the former could be taken care of in its appropriation to the latter.

59 Of course the financial responsibility of The American Society would have to be safeguarded by limiting the appropriations for the locals both in period and in amount, and making them conditioned upon a return from the local satisfactory both in quantity and quality.

60 The word "local" has been used in the foregoing as descriptive of the affiliated body, inasmuch as usually such a Society will be made up of those residing in or near a city or town. There is nothing in the plan however to preclude an organization already existing and made up of specialists in any line, from asking affiliation with The American Society under its provisions. The body may now be national, and having for its special topic of discussion the engineering of the motor vehicle, or that of the production of artificial cold, or certain sanitary problems with a mechanical outlook. They would benefit by such affiliation and they would at the same time strengthen The American Society of Mechanical Engineers, and sacrifice nothing themselves.

61 The writer therefore as he lays down his official insignia of service after these many years, leaves the foregoing suggestions for the elaboration of his successors. All the organic change which would be necessary would be the creation of a Standing Committee on Affiliated Societies with the required By Laws for its guidance, on the same footing as the Research Meetings, Publication and Library Committee, now in existence. The rest the Council may provide for by resolutions and standards in the Secretary's office.

62 If these ideals and possibilities shall prove to be practicable and realized, the opening of the new Engineering Building and the twentieth century will make the beginning of an era of progress of prosperity of splendid usefulness and brilliant achievement which will give to the Society position and recognition which has never been dreamed of before.

THE SPECIFIC HEAT OF SUPERHEATED STEAM

By PROF. CARL C. THOMAS, ITHACA, N. Y.
Non Member

The specific heat of superheated steam is of interest to engineers because upon it depend the answers to the two following questions:

a How much does it cost, with given efficiency of steam-heating apparatus, to produce superheated steam of given pressure and temperature, at a given rate?

b What amount of heat energy may be counted on as available in unit weight of superheated steam of given pressure and temperature?

2 Since the specific heat of any substance is the quantity of heat required to change the temperature of unit weight through one degree, without producing any other physical or chemical change, and since this quantity may or may not depend upon the initial temperature and pressure of the substance under consideration, it follows that the specific heat may be practically constant, as in the case of water, or variable, as with gases. If the latter, the true specific heat *or specific heat at a point,* must be considered.

3 In some calculations it is necessary to have a knowledge of the value and law of variation of the *mean* specific heat, or the average amount of heat required per degree in changing the temperature of a substance from some assumed starting temperature to some other temperature. This *mean specific heat* is more often required in engineering calculations than is the *specific heat at a point.*

4 The results given in this paper show both true and mean specific heats of superheated steam, the mean being for temperature ranges starting at the saturation temperature.

To be presented at the New York Meeting (December 1907) of The American Society of Mechanical Engineers, and to form part of Volume 29 of the Transactions.

5 The final form of apparatus was developed after a series of painstaking investigations extending over several years. These preliminary experiments are important in showing the advantage derived from certain improvements in the apparatus, and will therefore be first described.

6 Study of the characteristics of the flow of steam, superheated or otherwise, and with or without entrained water, have resulted in the development of the special apparatus devised by the author for the measurement of specific heat.

PRELIMINARY APPARATUS AND EXPERIMENTS

7 The following notes are intended to convey an understanding of the line of reasoning, and the method and apparatus employed by the writer and his assistants during the years 1905, 1906 and 1907.

8 The first experiments consisted in passing superheated steam through the bomb calorimeter shown in Fig. 1. In this calorimeter were electric resistance coils which served to raise the steam temperature from T_1 at entrance to T_2 at exit. The electrical energy and the subsequently condensed steam being measured, the mean specific heat could be calculated. A portion of the electrically supplied heat, however, was lost by radiation and conduction, notwithstanding the precautionary use of glass inlet and outlet tubes for the steam, and heat-insulating supports for the calorimeter.

9 Attempts to ascertain the radiation loss, by supplying just enough electrical energy to keep the temperature of the steam constant in its passage through the calorimeter, were but partially successful, owing to the impossibility of keeping surrounding conditions, or the rate of flow of the steam, unchanged during the various tests. The results of these experiments, about one hundred in number, are indicated in the lower right hand corner of Fig. 19.

10 A further disadvantage of this method and apparatus lay in the slightly higher pressure at the entrance thermometer than at the one at exit. This was obviated in the final experiments by employing only one thermometer, in a fixed position, for measuring both initial and final temperatures.

11 In order to eliminate various sources of error that had become apparent, two identical, electrically heated calorimeters were arranged in parallel, as shown in Fig. 2. Each containing shell was jacketed on the inside by steam at the initial temperature. The steam passed as indicated by the arrows, Fig. 1, through electric heating coils so insulated from the entering steam passage that the

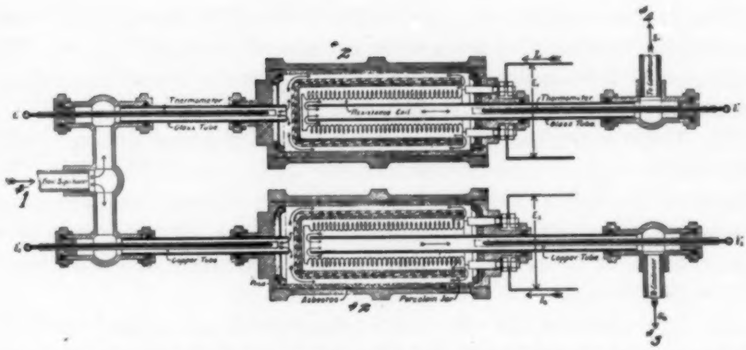


FIG. 1 SUPERHEATING CALORIMETERS FOR DETERMINING THE SPECIFIC HEAT OF SUPERHEATED STEAM

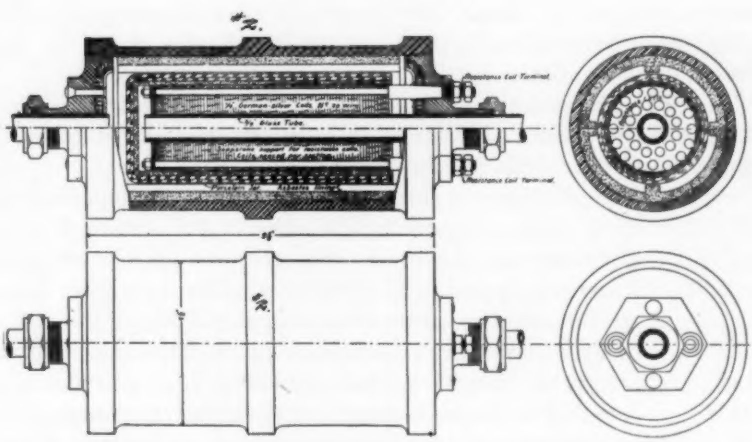


FIG. 2 SUPERHEATING CALORIMETER FOR DETERMINING THE SPECIFIC HEAT OF SUPERHEATED STEAM

further superheating was supposed not to affect the temperature of the steam next the exterior walls of the calorimeter, thus insuring the same radiation from both instruments.

12 To one calorimeter was supplied electrical energy sufficient to raise the temperature from some convenient temperature, say 250 degrees, to 270 degrees, and to the other to raise the temperature from the same initial temperature 250, to 290 degrees.

13 There being the same quantity of steam going through each calorimeter, and the radiation loss for each being the same, the difference in watts required to effect the different increases of temperature in the two calorimeters (in this case 20 degrees) represented the heat necessary to raise the given quantity of steam from 270 to 290 degrees.

14 Upon leaving the two calorimeters the steam passed through condensers, thence to accurately bored measuring tubes containing floats operating needle points. By so regulating the discharge valves of the calorimeters that the two needle points passed up the scale absolutely together, equal quantities of steam could be passed through the two calorimeters.

15 Glass tubes were employed at entrance and exit, in order to prevent conduction losses. The temperatures of incoming and outgoing steam were taken by means of thermo-couples placed in the glass inlet and outlet tubes.

16 In building up the apparatus, one after another of the causes of error in the previous investigation were attacked and eliminated by providing the following conditions:

a The production of a continuous supply of steam superheated to a given constant temperature and maintained at a given constant pressure. This was accomplished by passing steam from a small water tube boiler through an electric superheater, before which was placed a separator and a throttle valve. The steam pressure was kept uniform by a man at the throttle valve continuously observing a steam gage. The steam passing through the electric superheater at constant pressure was raised in temperature by a thoroughly controlled electrical input, until the steam, upon reaching the two calorimeters, was at the given desired initial condition, ready to be heated further in the calorimeters for determining the specific heat. The steam entered and left the two calorimeters through the glass tubes already described and passed directly over or around the thermo-couples for measuring temperatures.

b A uniform supply of electrical energy at constant voltage, and a means of varying the amount of electrical energy between narrow limits. This was obtained by the use of a motor generator set equipped with a Tirrel regulator. The resistance used for controlling the amount of current consisted largely of incandescent lamps. These were used because they are not much affected by temperature changes in the room, currents of air, etc. The input of electrical energy was measured upon a single milli-voltmeter so arranged as to read both volts and amperes. This was done to avoid errors in reading two separate instruments.

c Means for absolutely measuring the temperature of the steam entering and leaving the calorimeters. After an extended experience with the best mercurial thermometers obtainable in this country and abroad, it was found that the lack of constancy of the mercurial thermometer rendered it totally unfit for this class of work. Temperatures were therefore measured by thermo-junctions which are readily inserted in the desired position and which can be calibrated with accuracy. Platinum resistance thermometers were tried but displaced in favor of the thermo-couples.

d Means for eliminating the errors introduced by radiation of heat from the apparatus. This was done as already described by arranging for equal radiation losses from the two instruments. To make sure that the radiation losses were the same from the two calorimeters, special radiation runs were made by passing superheated steam through the calorimeters and introducing just enough electrical energy to equalize the entering and exit temperatures.

e Means for thermally isolating the apparatus and thus minimizing the loss of heat by conduction through pipe connections and supports. The pipe connections were the glass tubes described, and the supports were wooden blocks covered with Portland cement upon which calorimeters rested.

f Means for obtaining a continuous measure of the amount of steam passing through the calorimeters; intermittent weighing of the condensed steam is not satisfactory. The continuous measure was obtained by using the uniform diameter tubes containing the floats actuating needle points.

17 The apparatus was operated by Mr. C. E. Burgoon, Fellow in Sibley College in 1905–1906, and the great care and skill he bestowed upon the work resulted in the performance of about one thousand experiments, the results of which are shown in the lower right hand corner of Fig. 20. During this extensive set of experiments, however, it became apparent that the apparatus as a whole, while it provided for eliminating the errors described, was too complex and required too many accurate readings to be practical of operation to the degree of accuracy desired, under the circumstances. There were, for example, four thermo-junctions to be read as nearly simultaneously as possible; there was an auxiliary superheater to control; there was the discharge from two calorimeters to regulate and to measure, and the electrical energy supplied to the two calorimeters as well as to the auxiliary superheater to be controlled. However these experiments, occupying about a year, gave fairly reliable values for the specific heat of superheated steam, and showed in a general way what has been proved by the later experiments to be the law of variation. But the more important service of the experiments was to show the necessity for greater simplicity of apparatus.

FINAL APPARATUS AND EXPERIMENTS

18 The regularity of the final results, presented on Fig. 5, 6, 7 and 8, is due primarily to the fact that the apparatus has been simplified by the discarding of a great deal of what formerly seemed essential. One of the chief improvements came with the development of the steam calorimeter shown in Fig. 3. This calorimeter, while it is used for determining the quality of steam, has, on account of its simplicity of construction and operation, been found specially well adapted for determining the specific heat of superheated steam.

19 The apparatus used in the final experiments consisted essentially of the following:

- *a* A source of steam under complete control;
- *b* A source of electrical energy under complete control;
- *c* An electrically heated calorimeter containing a single thermo-junction, shown at *E F*, Fig. 3, introduced immediately into the steam and capable of accurately measuring the temperature of the same. The details of the apparatus are such that all conditions are under the control of an operator standing at a table where all readings are taken.

20 The calorimeter, Fig. 3, is in a vertical position and receives steam from the boiler and separator, through the steam entrance *A*

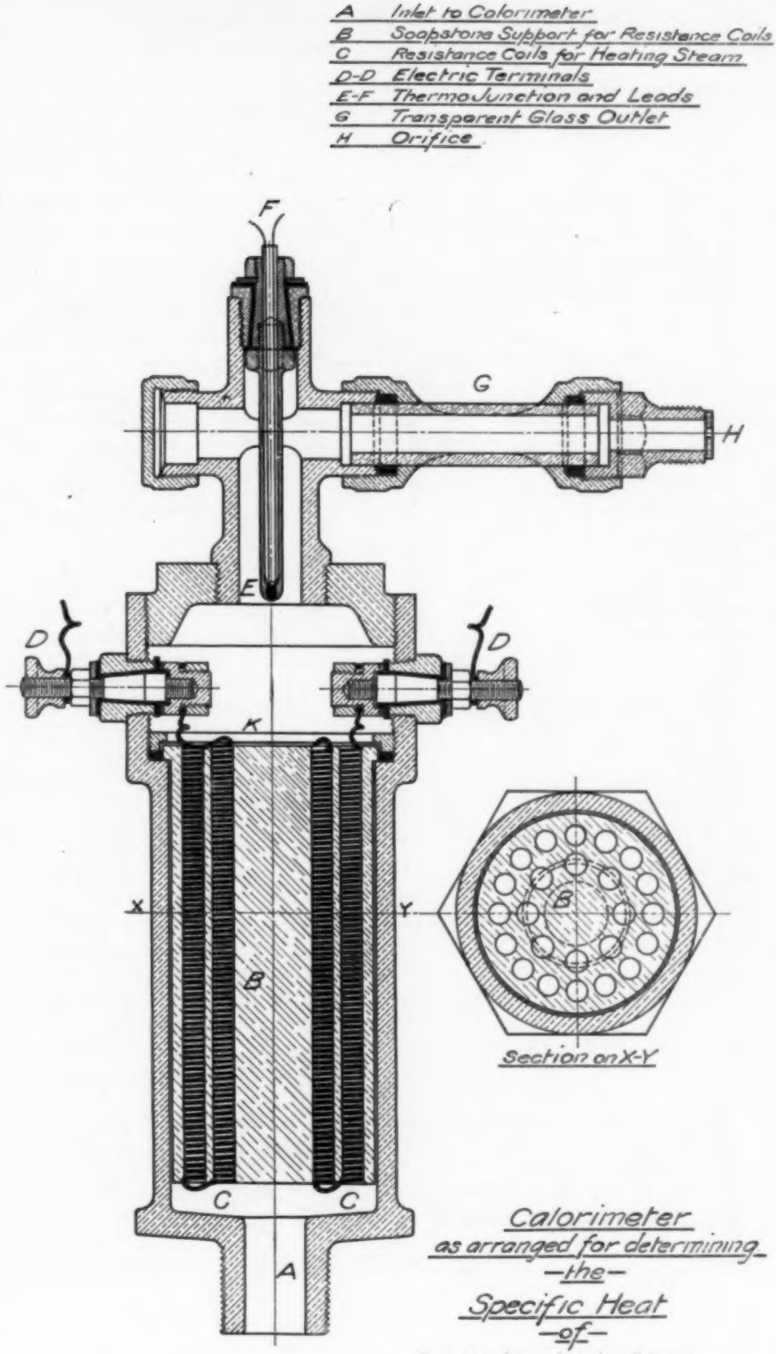


FIG. 3
Scale Approximately Half Size

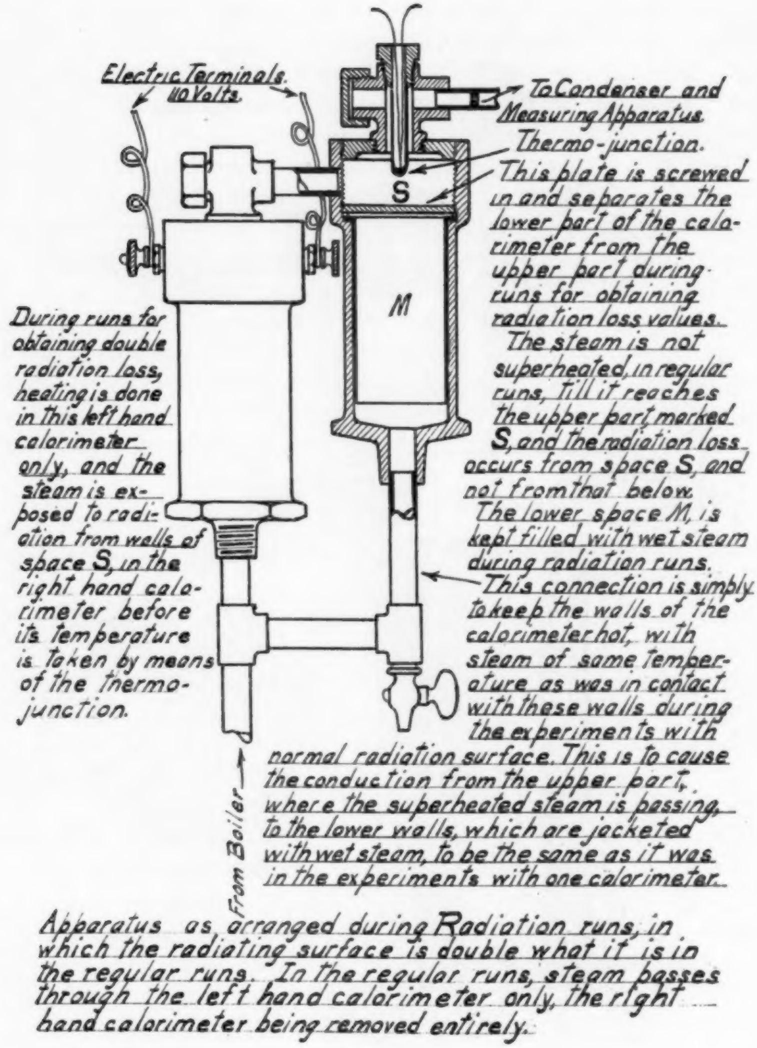

Electric Terminals.
110 Volts.
To Condenser and Measuring Apparatus.
Thermo-junction.
This plate is screwed in and separates the lower part of the calorimeter from the upper part during runs for obtaining radiation loss values.
The steam is not superheated, in regular runs, till it reaches the upper part, marked S, and the radiation loss occurs from space S, and not from that below.
The lower space M, is kept filled with wet steam during radiation runs.
This connection is simply to keep the walls of the calorimeter hot, with steam of same temperature as was in contact with these walls during the experiments with normal radiation surface. This is to cause the conduction from the upper part, where the superheated steam is passing, to the lower walls, which are jacketed with wet steam, to be the same as it was in the experiments with one calorimeter.
S
M
During runs for obtaining double radiation loss, heating is done in this left hand calorimeter only, and the steam is exposed to radiation from walls of space S, in the right hand calorimeter before its temperature is taken by means of the thermo-junction.
From Boiler
Apparatus as arranged during Radiation runs, in which the radiating surface is double what it is in the regular runs. In the regular runs, steam passes through the left hand calorimeter only, the right hand calorimeter being removed entirely.

FIG. 4

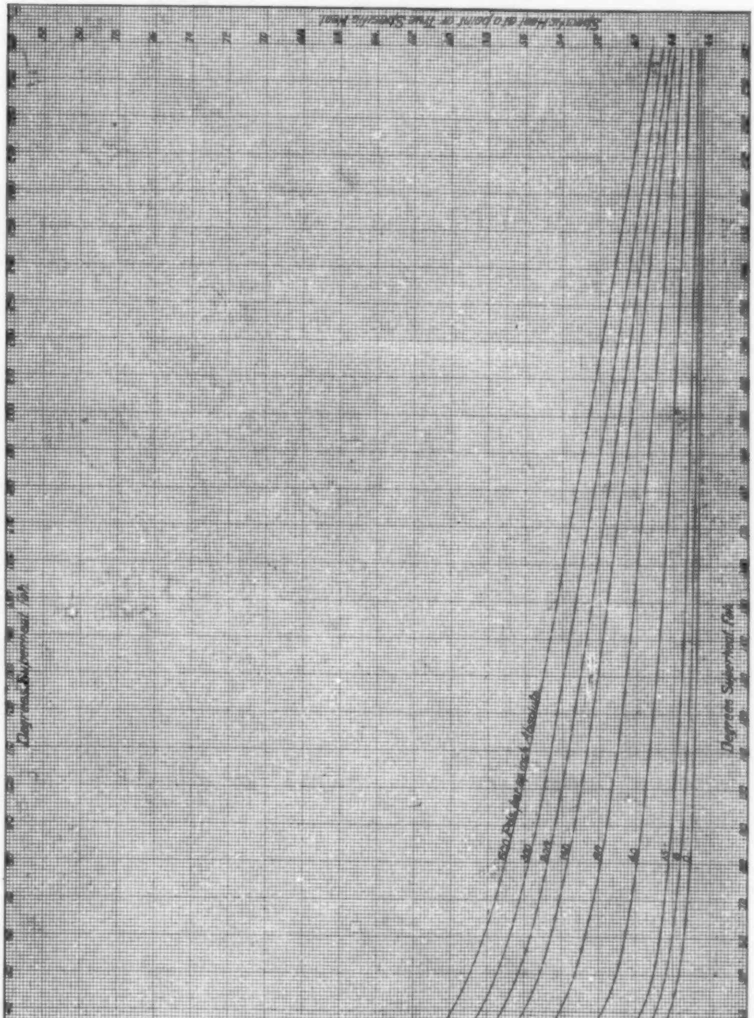


FIG. 5

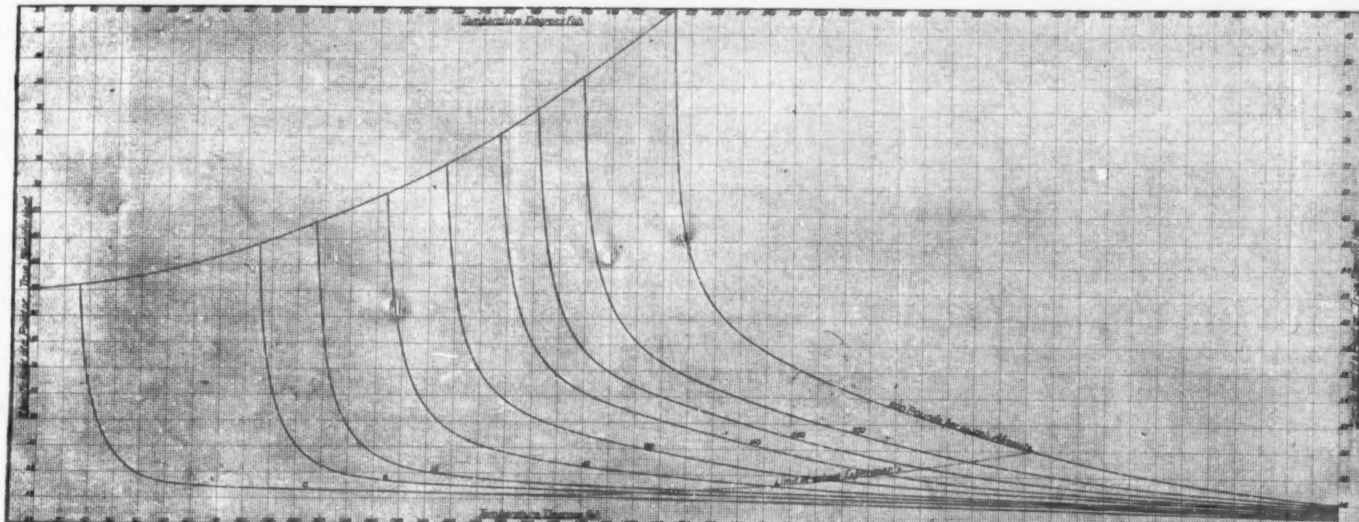


FIG. 6

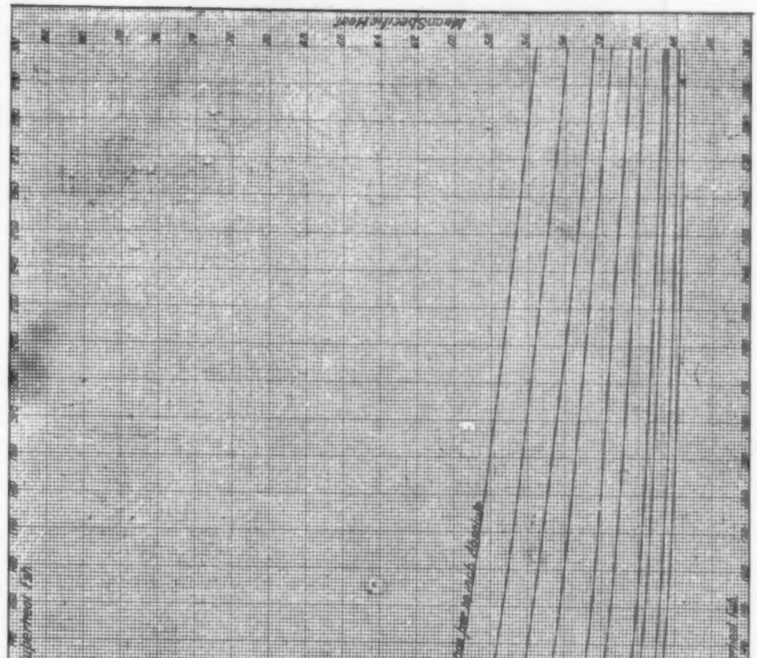

Mean Specific Heat
Degrees Superheat Fah.
Degrees Superheat Fah.
Mean Specific Heat

FIG. 7

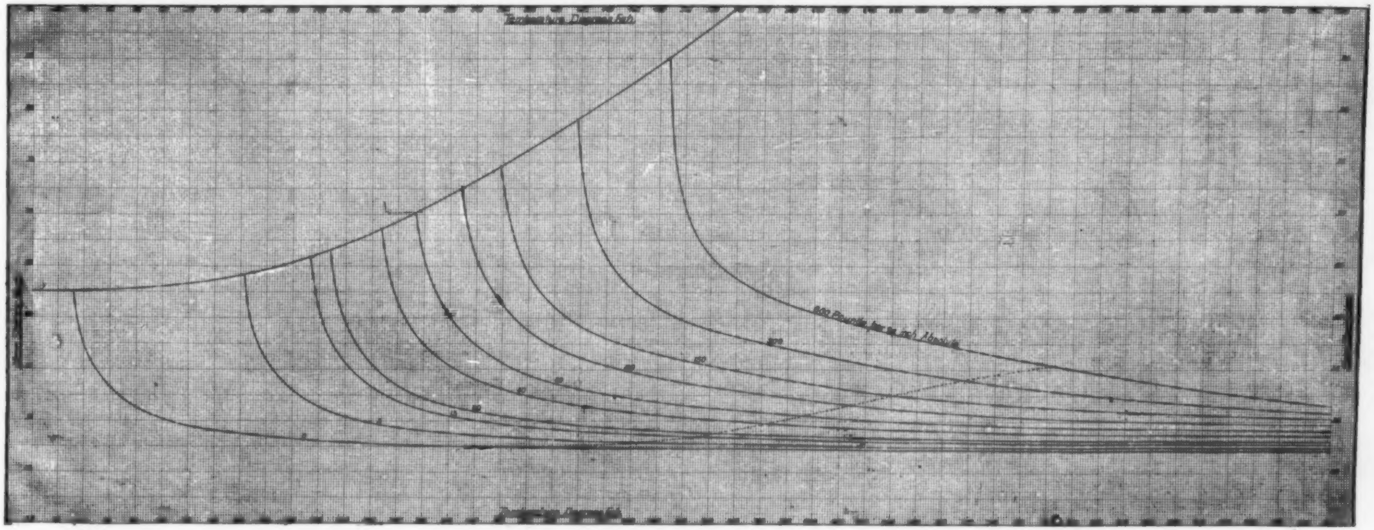


FIG. 8

to the calorimeter. This steam carries moisture along with it, into the small vertical holes containing the resistance coils *C*, Fig. 3.

21 If all the conditions are steady, and sufficient electrical energy is being introduced at a constant rate, the moisture is evaporated from the steam and the whole amount of steam is superheated to some fixed temperature depending upon the electrical energy supplied and the conditions of the entering steam. If the proportion of water brought in with the entering steam increases or decreases, the temperature as shown by the thermo-junction *E* indicates such change by an immediate fall or rise. Thus, if the percentage of water increases, the constant supply of electrical energy is not sufficient to raise the steam temperature as high as it could when it had less evaporation to perform before beginning to superheat. The relative constancy of all conditions is therefore shown by the degree to which the image on the screen showing the electromotive force of the thermo-junction *E*, remains fixed in position. It requires two or more hours' time after starting the apparatus preparatory to making a test for all conditions to become absolutely steady. When the conditions have become steady, there is passing through the space above the heating coils *C*, and about the thermo-junction *E*, superheated steam of a given temperature and pressure, flowing at a given constant rate. The electrical energy supplied is doing the following three things:

a Evaporating the moisture brought in with the steam.

b Superheating the total amount of steam.

c Heating the surroundings because of radiation from the calorimeter.

22 The velocity of the steam through the coils is comparatively very low, from about one and one-half feet per second at 500 pounds pressure absolute, to 18 feet per second at 7 pounds pressure absolute. The higher velocity at low pressures is due to the greatly increased volume per pound of steam. The vertical position of the calorimeter is an important feature, first because the steam and water are distributed more nearly uniformly than they would be if the calorimeter were horizontal; second, because the superheated steam rises at once into the small space above the coils and attains a uniform temperature as it passes out through the constricted passage about the thermo-junction. The calorimeters in the series of experiments already described were horizontal.

23 The experience thus gained led to adopting the vertical position, and the advantages of this were at once apparent. By careful study of the steam as it passed through the glass exhaust nozzle, *G*, it was found that the thermo-junction would indicate no rise of

temperature above that of saturated steam so long as water was going through with the steam. As soon as sufficient electrical energy was being introduced to make the water disappear however, any further addition of energy caused a rise of temperature of the steam. In a horizontal position the distribution of the contents of the calorimeter is not so uniform, and the indications of the thermometer are less reliable than when the calorimeter is vertical. In the vertical position, when water is passing with the steam it collects upon the tube of the thermo-junction as well as upon the walls of the passageway, and dripping down off the end of the junction causes the latter to be in contact with the water as long as there is any water present.

24 It is thus possible to know with certainty when the steam has just become dry and saturated, and to distinguish between this condition and that of either wet or of superheated steam. A feature which contributes to the uniform evaporation of water and superheating of steam is that the spiral heating coils present a sinuous outline as one looks into the holes in the soapstone, and they prevent the vision from extending over the complete length of the holes. The steam and water are thus caused to come into very intimate and positive contact with the coils. The wire composing the coils is about 0.046 inches in diameter so that coils such as have been described present a considerable surface, and quite efficiently baffle the steam passing up through the 24 ¼-inch holes in the soapstone support.

25 After a sufficiently extended study had been made with the assistance of the glass outlet nozzle to render the determination of the saturation condition possible and positive, the glass was no longer used, and the apparatus was arranged and fitted up successively in the various ways shown in the sketches on Fig. 9, 10, 11 and 12.

METHODS BY WHICH THE RESULTS WERE OBTAINED AND CORROBORATED

26 The whole operation of drying the steam preparatory to evaporating it, and of superheating it to some desired temperature above that of saturation is done in the one calorimeter, shown in Fig. 3, and the temperatures are all read by means of one thermo-junction shown at *E F*. The apparatus thus consists essentially of one calorimeter, one thermometer, a source of steam and a source of heat in the form of electrical energy. It has been only through the discarding of one piece of apparatus after another, doing away with preliminary superheating, that the degree of uniformity shown by the curves has been made possible of attainment.

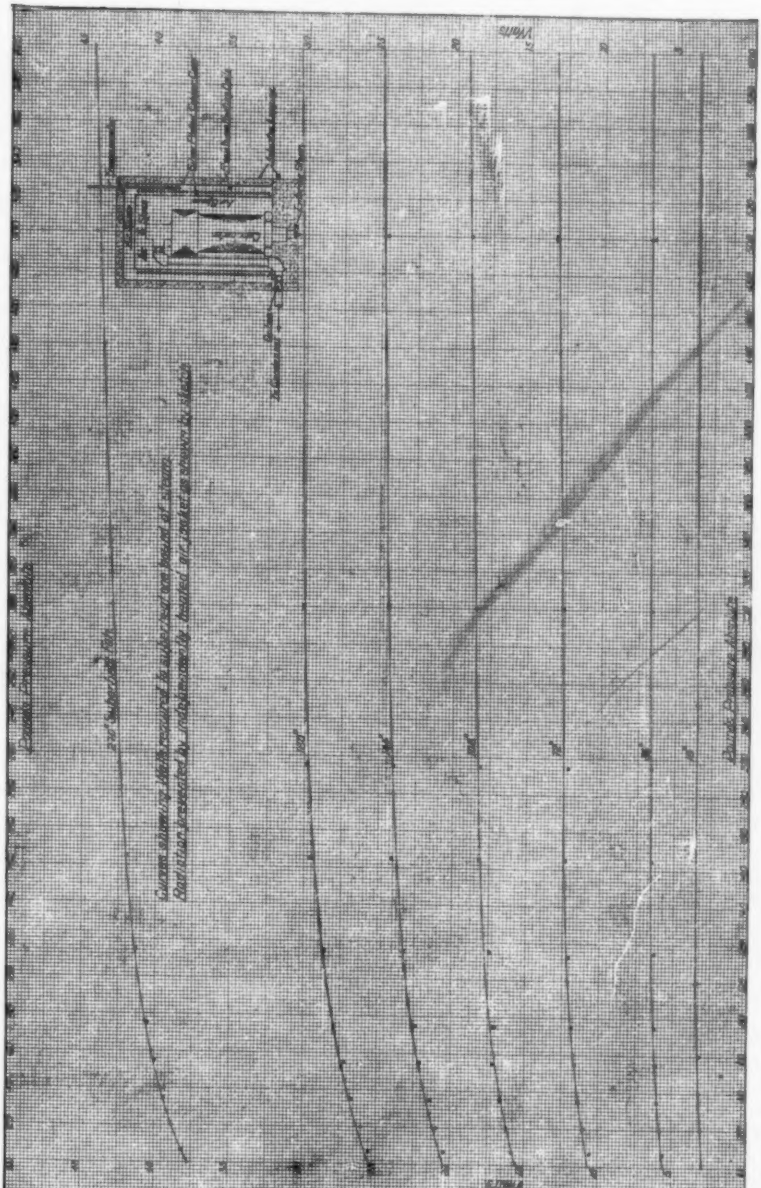


FIG. 9

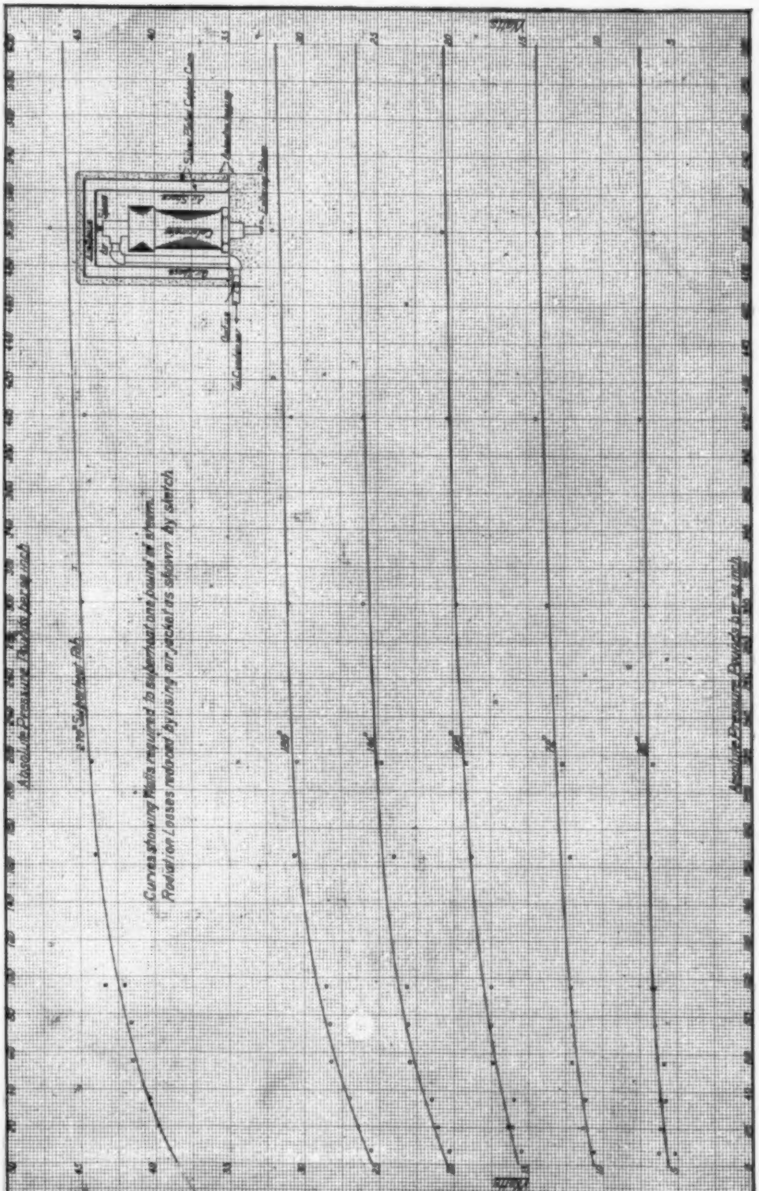

Curves showing Watts required to superheat one pound of steam.
Radiation Losses reduced by using air jacket as shown by sketch
Absolute Pressure Pounds per sq. inch
Watts

FIG. 10

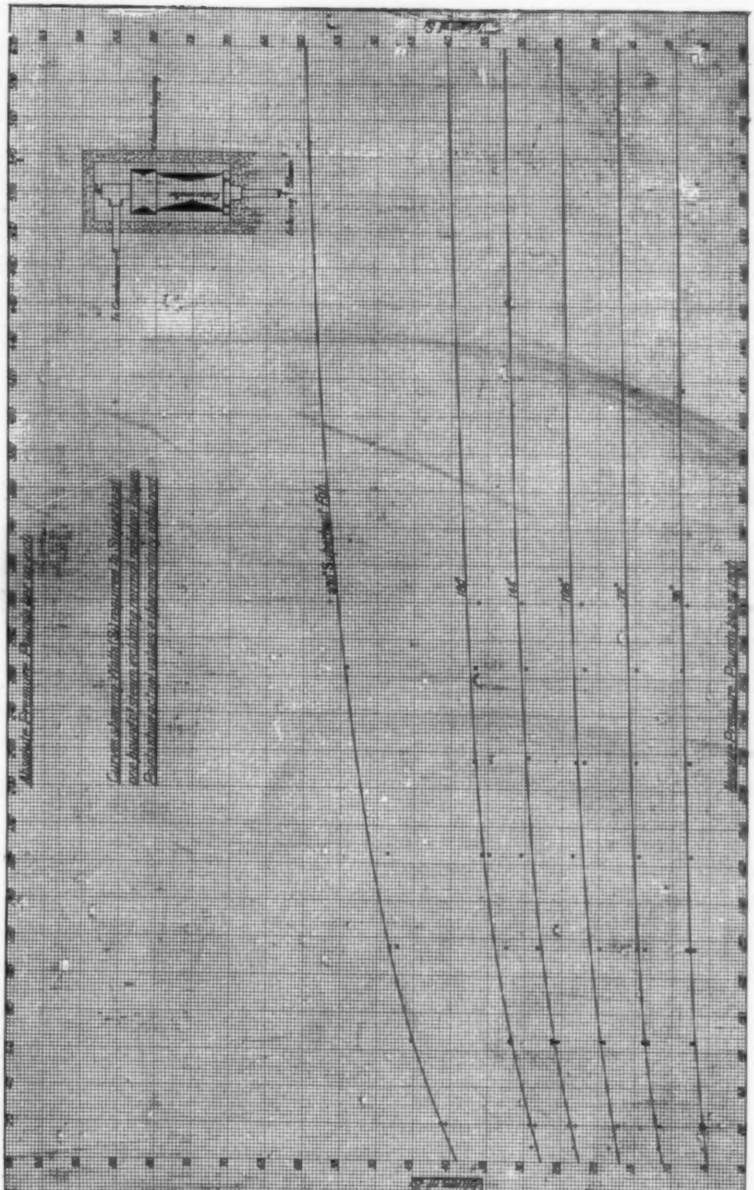


FIG. II

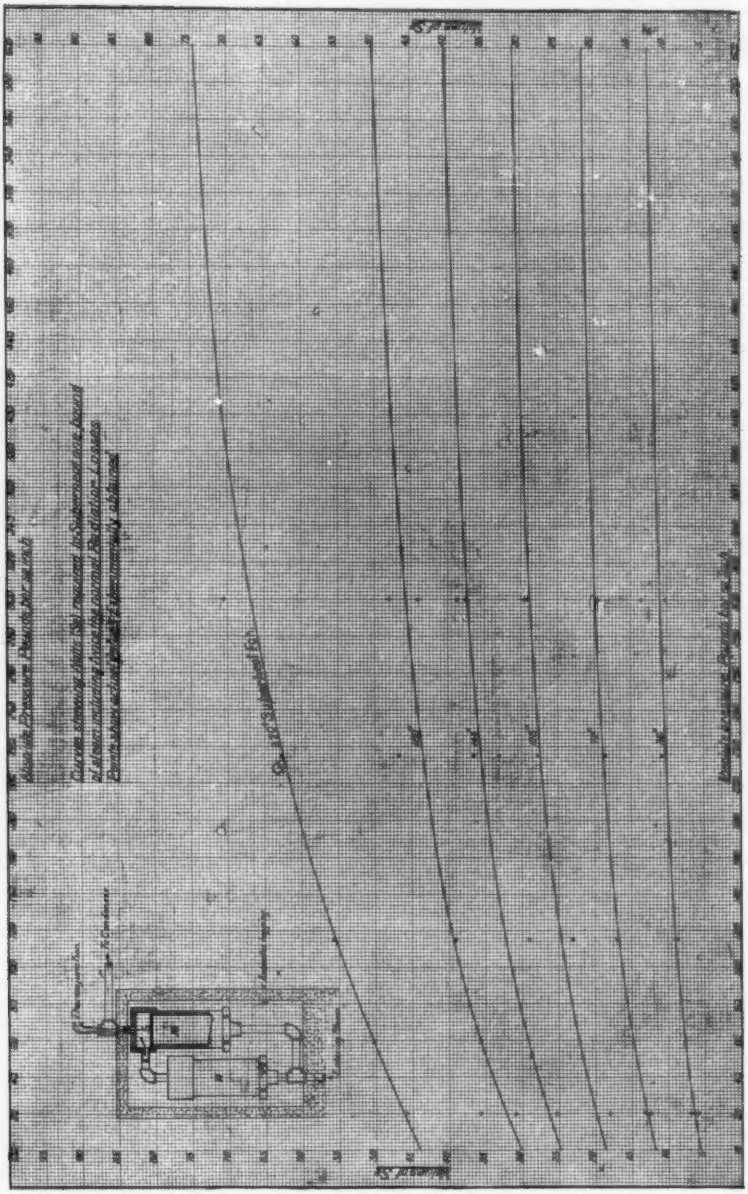


FIG. 12

27 Briefly, the method used is as follows: All conditions having been arranged so that they can be controlled, thus providing for practically absolute steadiness of steam pressure, voltage and steam supply, steam is started through the calorimeter and the whole system is allowed to run for several hours before taking readings. When finally steady conditions have been obtained, steam of a certain quality is entering the calorimeter. Electrical energy is introduced sufficient to dry this steam as indicated by the thermo-junction in the calorimeter. Any change in quality is at once indicated by temperature change as previously described. Standard conditions having been obtained—that is, a given quantity of steam passing through the calorimeter per unit of time and receiving just enough electrical energy to dry it and thus bring it up to the "standard" or dry steam condition; then enough more electrical energy is added to raise the temperature of the steam through a given range, either 20, 40, 60, 80, 100 or 150 degrees cent. corresponding to 36, 72, 108, 144, 180 and 270 degrees fahr. respectively.

28 The energy required to produce this rise of temperature having been noted, the initial standard (dry and saturated) conditions are gone back to by dropping out the energy introduced to give the range of temperature. This forms a check on the constancy of the standard condition. From these data specific heats including radiation from the instrument are calculated for the various pressures and temperature ranges employed.

THE QUESTION OF CONDUCTION AND RADIATION LOSSES FROM THE CALORIMETER

29 To minimize conduction losses the calorimeter is connected to the piping leading to and from it by means of a thin steel tube, turned to approximately $\frac{1}{2}$ inch outside diameter and bored $\frac{7}{16}$ inch inside.

30 To obtain a measure of the heat actually entering the steam entirely apart from radiation losses, and in order to verify the results, two independent methods were employed, and two independent sets of tests, each covering the entire field, were made as described below.

METHOD NO. 1

31 The first set of tests was made with the calorimeter simply lagged with magnesia sectional covering, as shown on Fig. 11. The whole range of pressures and temperatures was investigated with this arrangement. Then to find the radiation losses, the same experiments were repeated with the steam going through two calorimeters,

exactly alike, and in series as shown in Fig. 4, and in sketch on Fig. 12, so that there was twice the radiating surface *exposed to superheated steam* in the second case that there was in the first. It of course required more energy to produce the same temperature with twice the radiating surface, than it required with the original single calorimeter. Fig. 4, shows the arrangement of the calorimeters during runs in which the normal radiating surface was doubled. The legend accompanying the figure explains the reasons for the arrangement employed.

32 The curves for single or "normal" radiation are shown on Fig. 11, and for double or "twice the normal" on Fig. 12. These runs were made from 7 pounds absolute to 300 pounds absolute, while the subsequent runs, by the second method, were made from 7 pounds absolute to 500 pounds absolute. The same degrees of superheat were used in the two cases.

33 The difference in energy required to produce the same temperature difference in the two sets of experiments, is equal to the radiation loss. The results, after deducting radiation losses, are shown in Fig. 13, on which both constant temperature and constant pressure curves are drawn.

34 From the constant pressure curves the *true specific-heat* may be found as well as the *mean specific-heat*. On Fig. 14, are given the three sets of curves showing the watts required per pound steam for the various temperature ranges, including respectively twice the normal and the normal radiation losses, and also the watts required after deducting the radiation losses. The process will be made clearer by a reading of the following outline.

METHOD OF MAKING CALCULATIONS.

35 Let W_1 = weight of dry steam flowing per hour, in pounds;
W_2 = weight of superheated steam flowing per hour, in pounds;
E_1 = watts required to dry W_1 pounds steam per hour;
E_2 = watts required to dry and superheat W_2 pounds steam per hour through T degrees;
S = watts required to superheat 1 pound per hour through T degrees.

36 *Calculations including single radiation,* that is, radiation from one calorimeter. Let S_1 watts be required to superheat 1 pound steam per hour through *T* degrees including the watts radiated by the superheated steam

$$\text{Then } S_1 = \frac{E_2}{W_2} - \frac{E_1}{W_1}$$

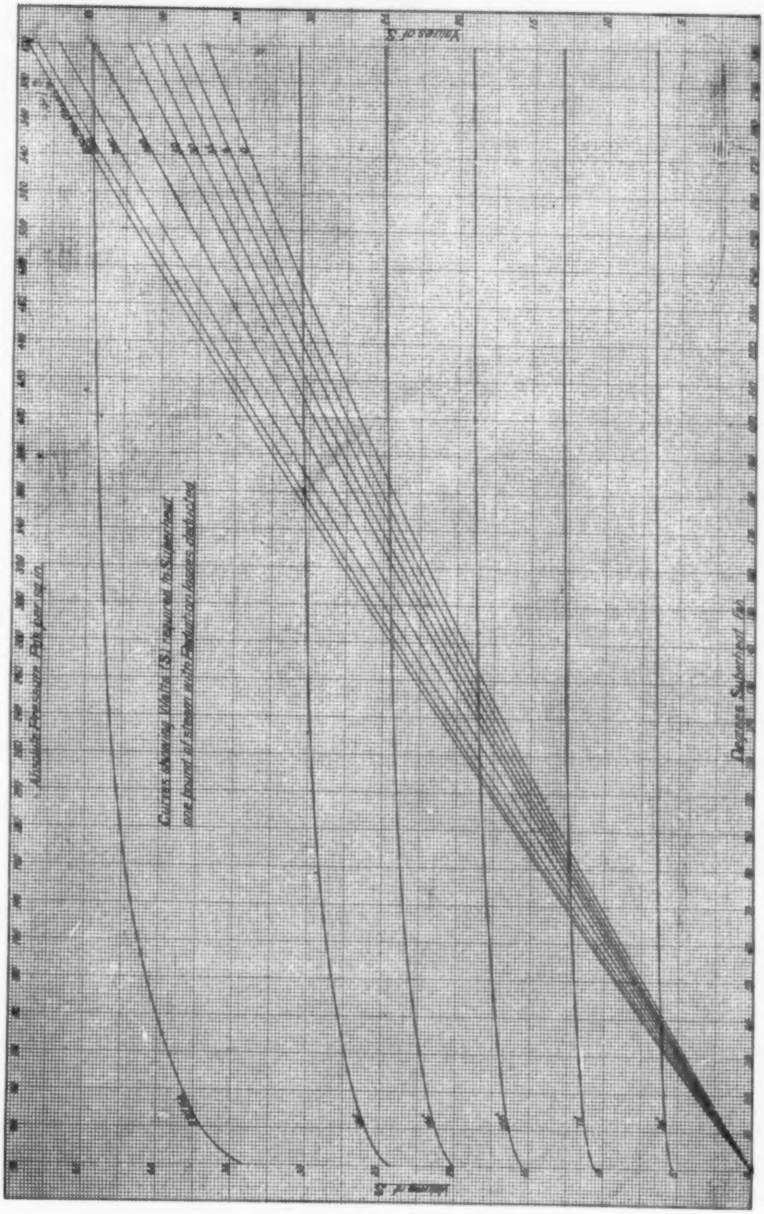


FIG. 13

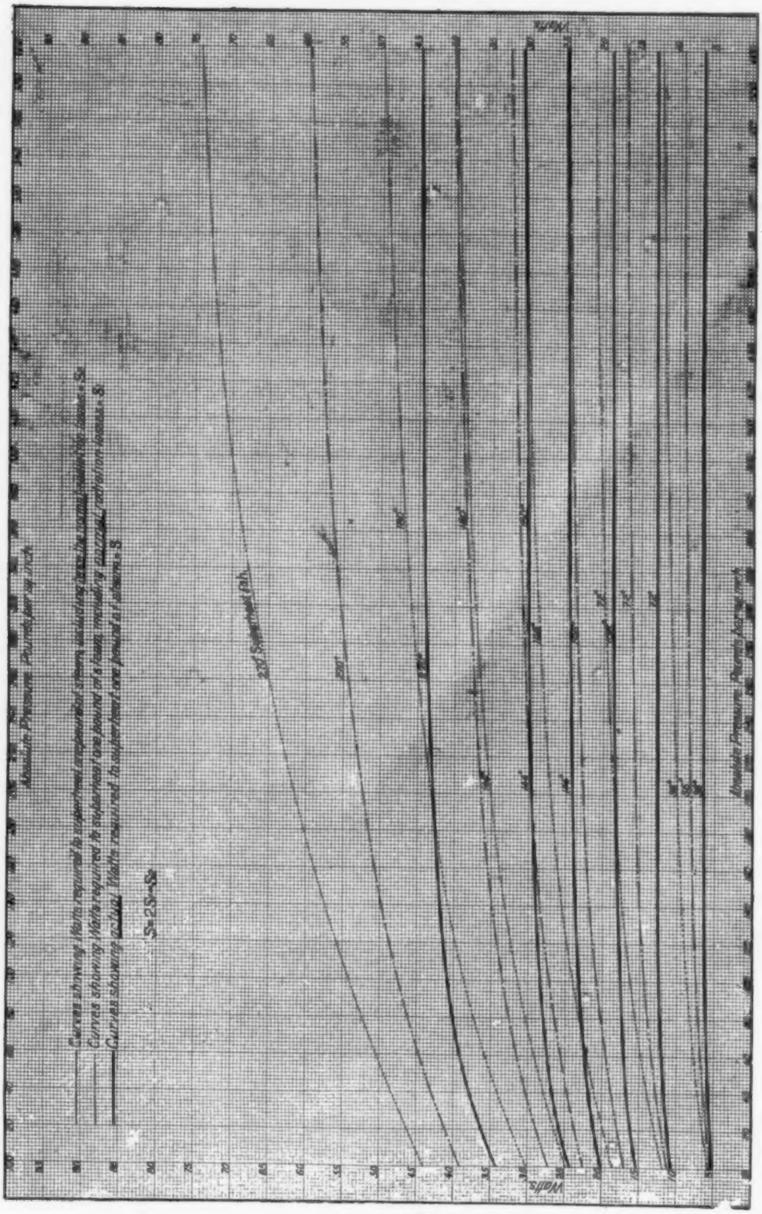


FIG. 14

37 *Double radiation* Let S_2 watts be required to superheat 1 pound per hour through T degrees when the steam is exposed to double radiation as shown in Fig. 4.

Then, if S equal the watts actually going into the steam per pound to raise its temperature T degrees,

When steam is exposed to single radiation

$$S_1 = S + \text{Radiation, or } 2S_1 = 2S + 2R$$

When steam is exposed to double radiation

$$S_2 = S + 2\text{Radiation, or } S_2 = S + 2R$$

$$\text{Subtracting,} \quad 2S_1 - S_2 = S$$

38 Since 1 watt hour = 3.412 B.t.u., the heat units required to raise one pound of steam through T degrees = 3.412 S, and the mean specific heat over that range of temperature is

$$C_p = \frac{3.412\ S}{T}$$

39 A study of the curves will show how important a feature the radiation from the calorimeter proved to be. Roughly, it varied from 12 per cent of the electrical energy introduced at low temperatures and pressures, to about 25 per cent at high temperatures and pressures.

SECOND METHOD

40 It now remains to be shown how the results just described were verified by an entirely different method of dealing with radiation, first by *greatly reducing radiation*, and making a complete series of tests. Second, by making the nearest possible approach to *eliminating radiation* and making another complete series of tests.

41 The reduction of radiation was accomplished by lagging consisting of two cylindrical silver-plated and polished copper cans, placed concentrically over the calorimeter as shown on Fig. 10. The cans rested upon a flat foundation of asbestos plastic, and the outer can was lagged with the same material. An air space thus existed between the calorimeter and the inner can, and one between the two cans themselves. The silvered and polished surfaces of the cans were for the purpose of reflecting the heat which tended to pass through the air spaces.

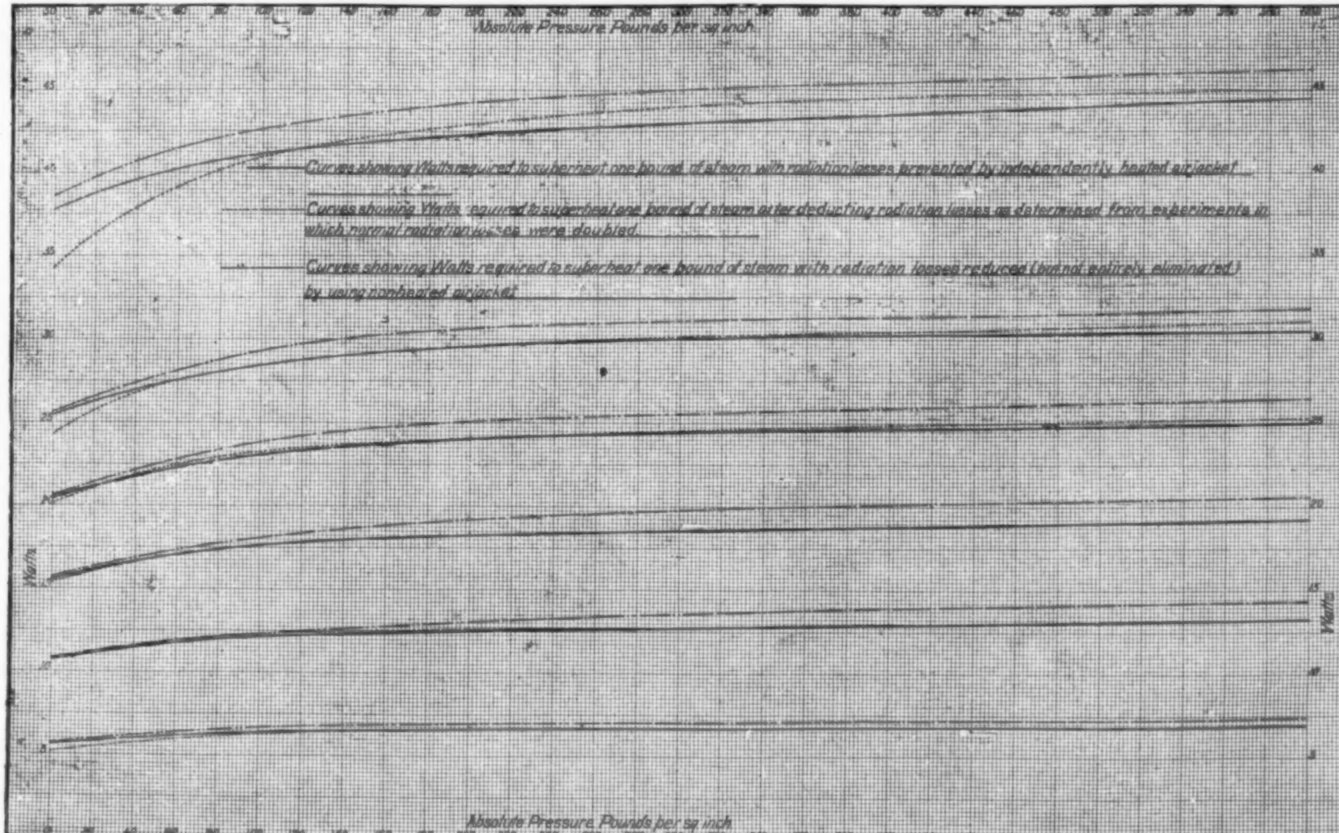
42 The result of the use of this lagging was the almost complete prevention of radiation. As an evidence of this the hand could be comfortably held on any part of the lagging even when the temperature in the calorimeter was 750 fahr. The curves obtained from this series of tests are shown on Fig. 10, and also by the broken lines on

Fig. 15, where comparative results are shown. By inspection of the curves on Fig. 15 it will be noted that the radiation varied from about 1 to 4 per cent at low temperatures, to about 2½ to 5 per cent at high temperatures, the increase being with increase of pressure in all cases, as well as with increase of temperature.

43 Finally, a coil of resistance wire was introduced in the space between the two cans, as shown on Fig. 9, and a thermometer was used to ascertain the temperature resulting from passing current through this coil. A complete series of tests was again made during each of which the air jacket space between the two cans was maintained at a temperature equal to that to which the steam was being superheated in the calorimeter. The results are shown by the curves on Fig. 9 and in tabular form in Table 1.

44 The comparative results of the tests are shown on Fig. 15. The results obtained by correcting for radiation by doubling it, and those obtained by eliminating radiation with the independently heated air jacket coincide almost absolutely for temperatures up to and including 144 degrees superheat. At 180 degrees a little too much allowance was made for radiation, when working by the first named method at pressures below 50 pounds, and above that pressure not quite enough allowance was made. The same is true in somewhat greater degree on the 270 degree curve. However the curves were intentionally plotted to a scale so large as to exaggerate differences, and it will be seen that the coincidence between the curves obtained by the two distinctly separate methods, is very pronounced. Further, the curves obtained with the independently heated air-jacket, and shown in full lines on Fig. 15, fair up into one family when cross-curves are drawn, (as on Fig. 17) with practically no deviation from the experimentally determined points as shown on Fig. 9. The curves on Fig. 9 are identical with those in full lines on Fig. 15. It should be noticed also that the results on Fig. 9 are the most regular of all those obtained in these experiments, and they were by far the most easily obtained experimentally, because uniform conditions are so easily maintained when the independently heated air-jacket is employed.

45 The curves on Fig. 15 showing results obtained with the silvered can insulation but without introduction of heat in the air-space fall just as would be expected with reference to the results shown in full lines. That is, radiation was greatly reduced, almost completely in fact, by the reflecting cans alone, but there was still some heat lost, as is shown by the somewhat greater amount of energy required to produce a given result, than was required when radiation



Absolute Pressure Pounds per sq inch
Curves showing Watts required to superheat one pound of steam with radiation losses prevented by independently heated airjacket
Curves showing Watts required to superheat one pound of steam after deducting radiation losses as determined from experiments in which normal radiation losses were doubled.
Curves showing Watts required to superheat one pound of steam with radiation losses reduced (but not entirely eliminated) by using nonheated airjacket
Watts
45
40
35
30
25
20
15
10
5
Absolute Pressure Pounds per sq inch

FIG. 15

was eliminated. The difference in energy required is seen to be very small at low temperatures, and increases naturally as the temperature in the calorimeter increases.

46 The final results as given on Fig. 9 and in full lines on Fig. 15, have been transformed from watts to thermal units on Fig. 16 and 17. From Fig. 17 either the mean specific heat, or the specific heat at a point, may be taken off directly. The upper curves are simply the reproduction to larger scale of the lower curves for the first 30 degrees of superheat.

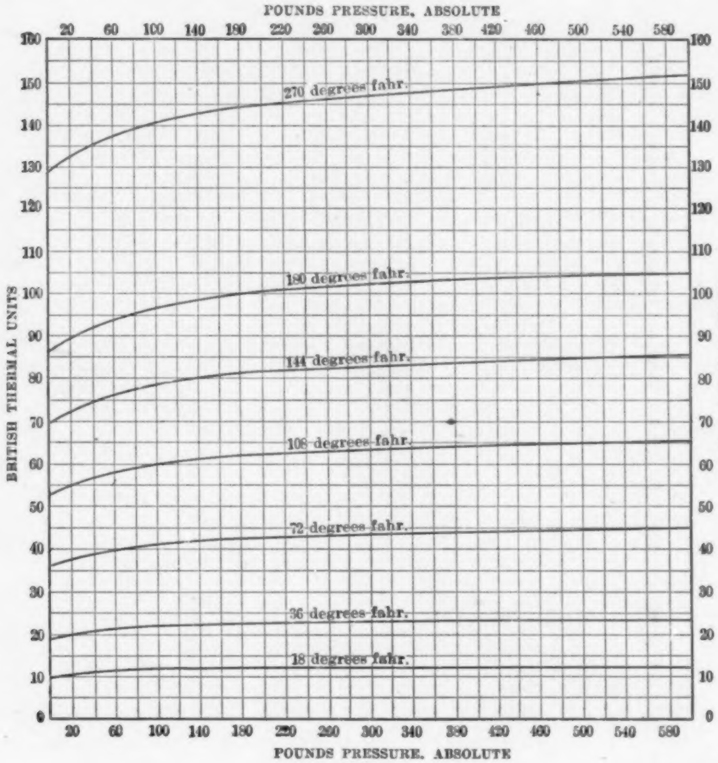


FIG. 16

47 The apparatus has been left in just the condition last described, with the independently heated air jacket within the silvered copper cans, and various corroborative tests have been made besides those presented in this paper. It is possible at the present time to reproduce at will such results as are given on Fig. 9 with the apparatus as it now stands.

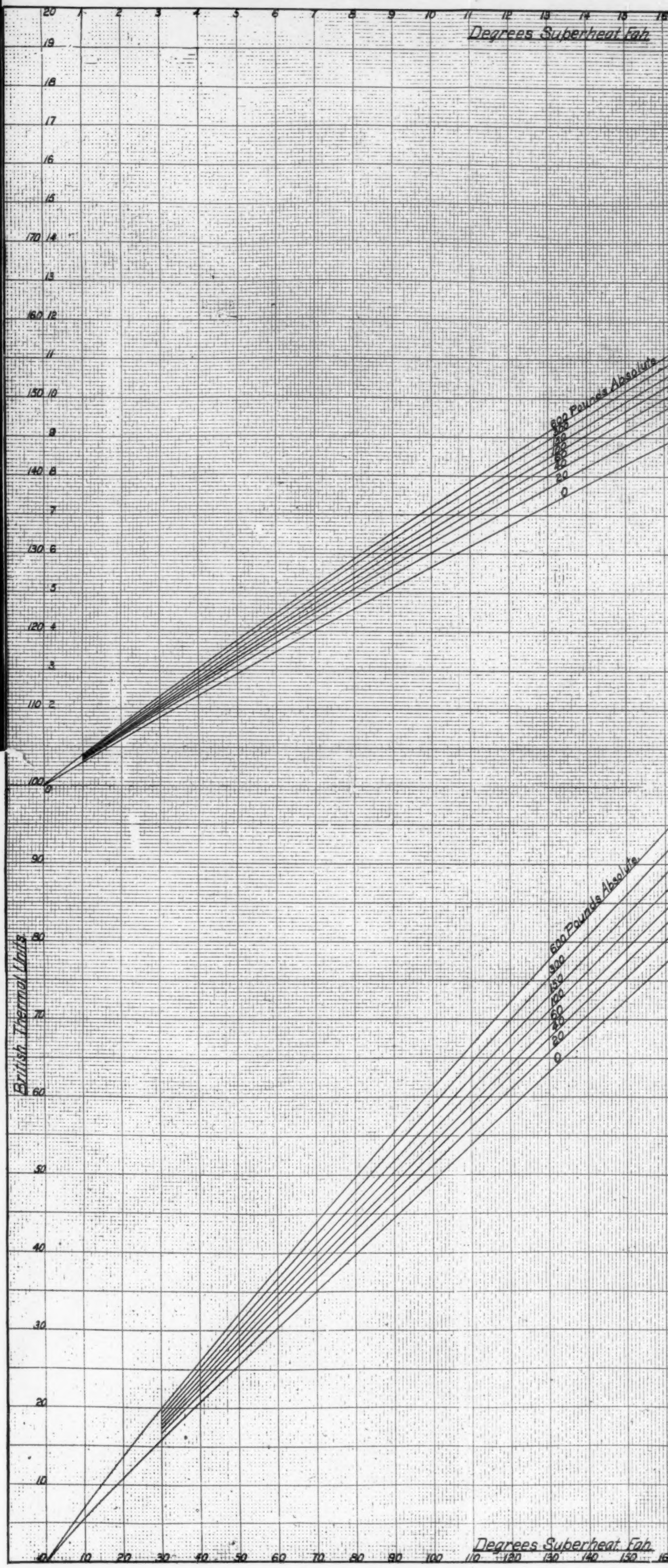

Degrees Superheat Fah.
600 Pounds Absolute
300
150
100
60
20
0
British Thermal Units
Degrees Superheat Fah.

FIG. 17

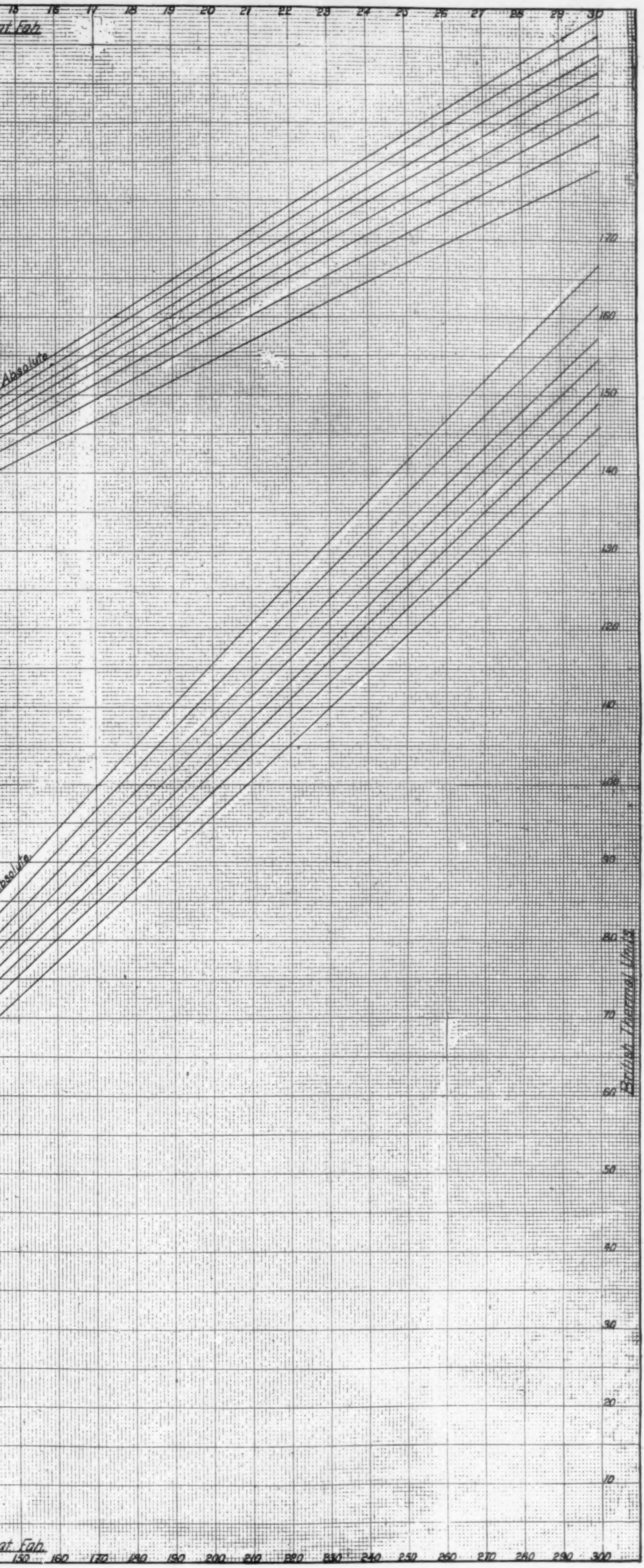

15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
at Fah.
Absolute
bsolute
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
British Thermal Units
at Fah.
150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300

FIG. 17

48 The zero line, or line of zero pressure, on Fig. 17, was obtained by extending the experimentally determined curves on Fig. 9 and 16 back to the line of zero pressure on those figures, by a process of fairing. Since the experiments included determinations at 7 pounds absolute pressure, the distance through which it was necessary to extend the curves was very small.

49 The curves on Fig. 9 were plotted from the original data, which are given in full in Table 1.

50 In this connection it is of interest to note that the lowest number of degrees of superheat used in the experiments made before August 1, 1907 was 20 degrees cent. or 36 degrees fahr. It was later desired to corroborate the results obtained by extending the curves on Fig. 17 from the 20 degrees cent. points through zero, which had been done by the process of fairing the curves, aided by certain experimentally determined points obtained during low superheat runs. Two months and a half after the experimental work originally contemplated was finished, it was decided to explore the region of 10 degrees cent. superheat (18 degrees fahr.) and the curve shown at the bottom of Fig. 9 shows the results of these experiments. By computing specific heat from this curve as reproduced in thermal units on Fig. 16 it will be found that the curves on Fig. 17 are completely checked and verified, for a position midway between zero degrees superheat, and 20 degrees cent. that is, at 10 degrees cent. or 18 degrees fahr.

(*g*) COMPARISON OF RESULTS WITH THOSE OBTAINED IN VARIOUS OTHER INVESTIGATIONS OF THE SUBJECT

51 That the specific heat of steam is not constant has been believed by physicists and engineers for some years, and testimony from many sources has been unanimous in confirming the belief that it varies in some way; either with change of temperature, or of pressure, or with both temperature and pressure.

52 In 1904 the writer had occasion to make use of values of the total heat of superheated steam, and as a matter of convenience plotted constant-pressure and constant-heat curves in a temperature-entropy diagram, using values for the specific-heat of superheated steam such as had been published at various times. The first set of values used, assumed the specific heat to vary with the pressure only, the variations being represented about as shown in the lower right hand corner of Fig. 19. The resulting constant-heat curves are shown by the broken lines BB. The values of constant-heat are seen to

plot into fairly smooth curves until the curve of 1250 thermal units is reached, although that curve begins to show uncertainty of character. As higher values for the heat contents are used, such as 1300, 1350, etc., the curves become more and more irregular, finally entirely departing from the characteristics possessed by the curves of lower heat contents. In other words, the curves do not form a uniform set, or family, showing similar characteristics. Examination in this manner, of various results at that time available, formed the initial step, showing the necessity for, and leading on to, the present investigation.

53 It should be said here, that the mere fact that certain values, assumed to represent the specific heat of steam, plot into smooth curves, is not necessarily any indication that those values do really represent the specific heat of steam, or of any other substance. But if any assumed values of specific heat, or of any other physical characteristic in nature, do *not* plot into curves of a common family, it is highly probable that the correct determining coefficients have not been used. Many curves however, could be found and used tentatively to represent the variation of the specific heat, which would, for mathematical reasons, modify the expressions used in calculation of the heat-diagram so as to give smooth and related curves.

54 For example, the use of a *constant* value will give a family of regular constant-pressure and constant-heat curves. The curves *AA*, Fig. 19, are plotted with the value 0.48, and are seen to fall into a family of smooth curves, as would be expected from mathematical considerations, to be the case for any constant value. But, for the reasons stated, this does not prove that the actual specific heat has a constant value. Curves *CC* on the same plate show the results obtained in the present investigation and are seen to fall into one family maintaining definite and regular characteristics.

55 On Fig. 20 the results obtained by Mr. Burgoon with the apparatus shown in Fig. 1 and 2 are plotted in the lower right hand corner, and constant-pressure and constant-heat lines are plotted for the superheated region of a temperature entropy diagram. At about 1270 thermal units the curves of constant heat begin to be uncertain in character, and above that value they gradually change direction, finally assuming entirely different characteristics from the lower heat curves.

56 On Fig. 18, the black points are those belonging to the results of the present investigation. The curves marked *A*, through them retain the same characteristics throughout, even up to the highest temperatures and pressures. The points for 6 and for 15 pounds

absolute, at very high temperatures, are slightly higher than the curve but not enough so to change its character.

57 The broken line curves, marked *B*, Fig. 18, are plotted from the results of the work of Messrs. Knoblauch and Jakob, published in the *Zeitschrift des Vereins Deutscher Ingenieure*, Vol. 51, page 81, 1907. At 1250 thermal-units, the curve of constant-heat begins to waver, but is almost straight, and at higher values the curves turn down at the high pressure ends, tending to depart more and more from the family characteristic. This is largely due to the fact that the curves of specific heat as determined by these investigators show a decrease of the specific heat with increasing temperature until a minimum is reached, for each pressure, after which the specific heat *increases* with increase of temperature. An increase in the value given to the specific heat tends to lower the curves of constant-heat, because the greater the specific heat, the smaller will be the temperature range through which it is necessary to heat the steam in order to give it a certain increase in heat-contents.

58 On the other hand, a continually decreasing specific heat tends to keep the high pressure ends of the constant-heat curves up and to cause the curves to remain in one family. It will be appreciated readily that the higher the temperature and pressure to which one is attempting to work experimentally, the more difficult it is to control radiation losses. If these losses are not thoroughly allowed for an experimenter is likely to arrive at too high values for specific heat in the higher temperature ranges, because, due to unaccounted for radiation losses, it *appears* that more heat is being expended to superheat the steam than is in reality going into the steam. The author had this experience in early investigations and it is probable that it has been the common experience and one which led to the belief some years ago that the specific heat of steam was very much higher than it has since been proved to be.

59 It will be noted from Fig. 18 that the constant heat curves, plotted from the values of specific heat given by Messrs. Knoblauch and Jacob are in general quite closely in agreement with the results of the present investigation excepting where the change in method of variation occurs, but the lack of regularity of the constant-heat curves plotted from their results indicates that the true law of variation of specific heat is not expressed by the curves, for the entire range of temperature covered by the experiments.

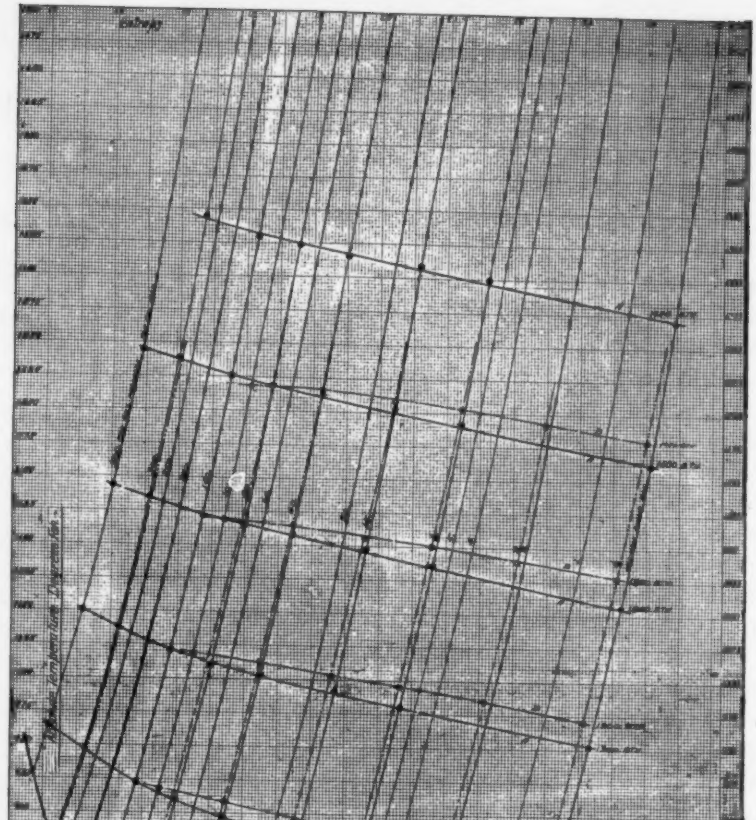


FIG. 18

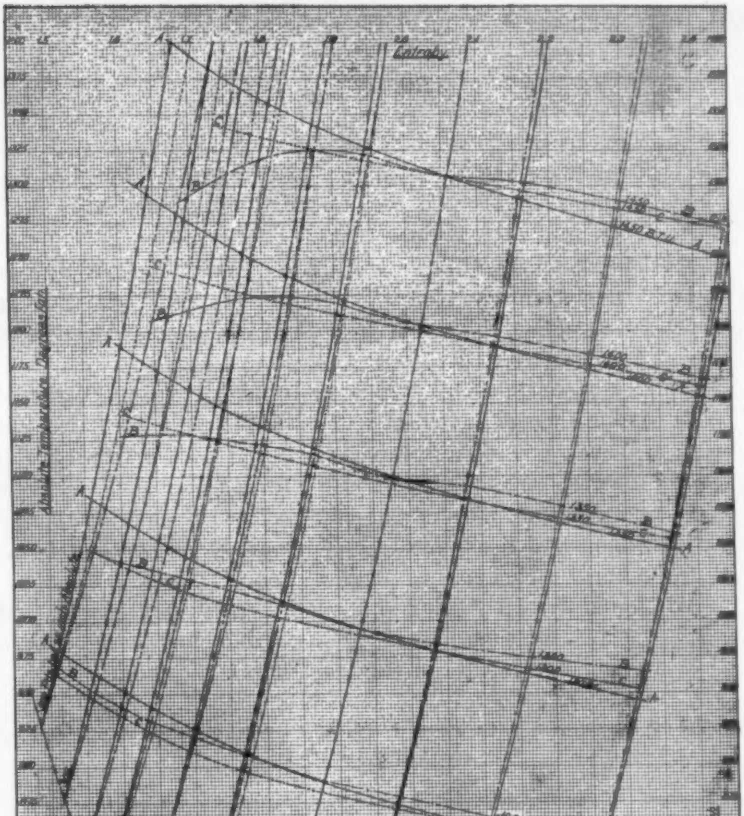

Entropy
A — A. Assuming Specific Heat to be constant and equal to 0.48
B — B. Assuming Specific Heat to vary with Pressure only as shown on Sketch B.
C — C. From Specific Heat values determined in the present investigation
Sketch B
Specific Heat
Pounds Pressure Absolute
Entropy

FIG. 19

CONCLUSIONS

a The specific-heat of superheated steam varies with both pressure and temperature. It increases when the pressure of the steam increases and diminishes with an increase in the temperature.

b The specific heat increases and decreases more rapidly when near the saturation point, with increase of pressure and temperature, respectively, than is the case in conditions more remote from the saturation point.

c These conclusions apply over the whole range covered in the present investigation, which include pressures from seven pounds absolute to five hundred pounds absolute per square inch and up to 270 degrees fahr. superheat, for all pressures employed. The values of the specific heat and the laws of variation are shown on Fig. 5, 6, 7 and 8 inclusive.

d The Mollin Heat Diagram, Fig. 21, forms a graphical steam table, the superheated region of which has been calculated from the results of the present investigation.

METHOD OF RECORDING DATA FROM TESTS AND OF MAKING CALCULATIONS, IN FINAL EXPERIMENTS

TEST ON SPECIFIC HEAT OF SUPERHEATED STEAM

Test no. ....

Date.......... 19..........

Pressure.......... lb. absolute

Temperature of steam leaving calorimeter .... cent.......... fahr.

Temperature of steam entering calorimeter .... cent.......... fahr.

Rise of Temperature in Calorimeter .... cent.......... fahr.

Time of ending test .... hr.......... min.......... sec.

Time of starting test .... hr.......... min.......... sec.

Duration of test .... hr.......... min.......... sec.

Water gage at end of test.......... lb.

Water gage at beginning of test.......... lb.

Water obtained during test.......... lb. when E_1 watts are being introduced.

Water obtained during test.......... lb. when E_2 watts are being introduced.

E_1 = Watts req'd to dry.......... lb. steam per hr. = ...

E_2 = Watts req'd to dry and superheat.......... lb. steam per hr. = ...

Pounds superheated steam flowing per hr.......... $= W_2$

Pounds dry steam flowing per hr.......... $= W_1$

True amp.......... True Volts.......... Watts..........

Room temp.......... cent.......... fahr.

Condensed steam temp.......... cent.......... fahr.

Microvolts.......... Corresponding temp.......... cent.......... fahr.

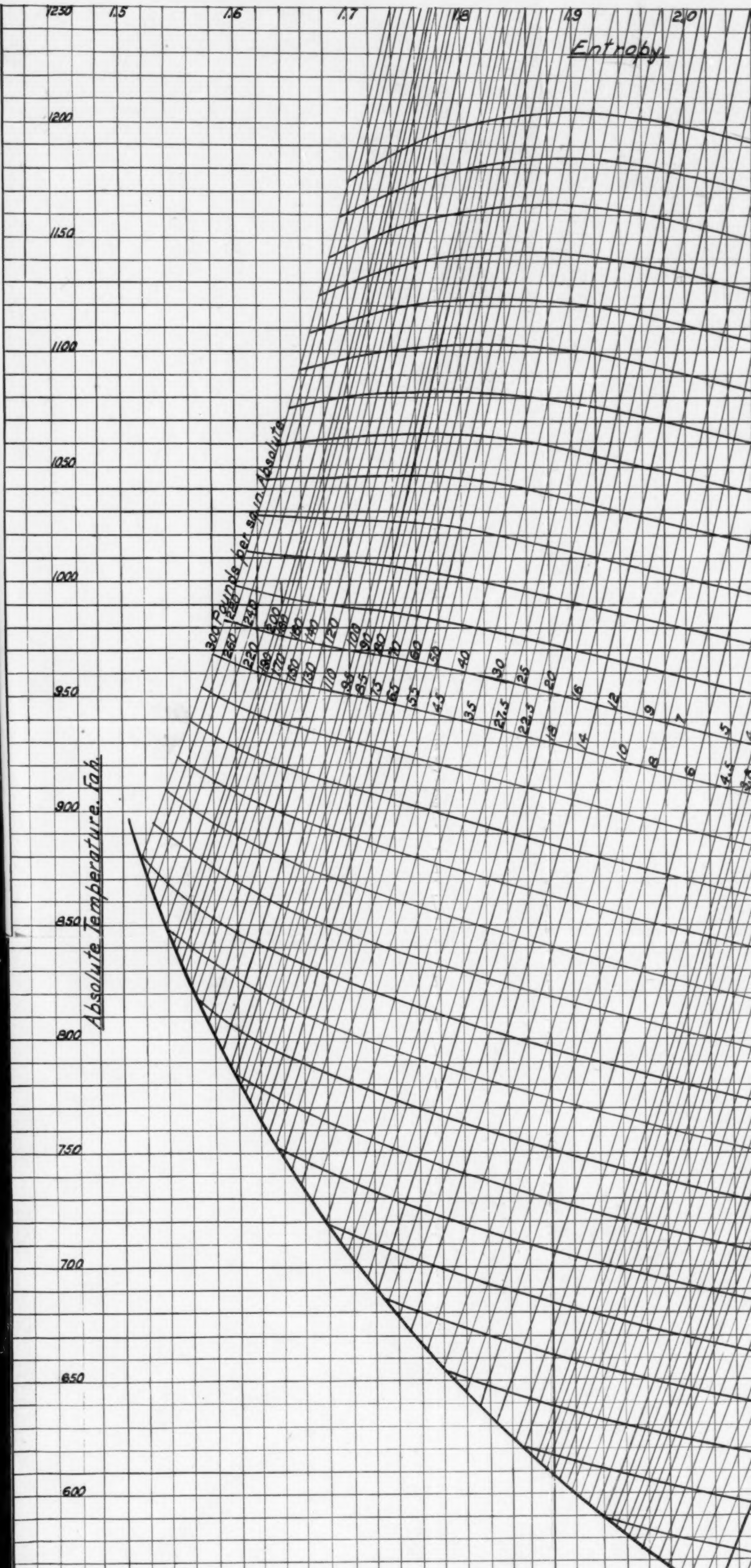
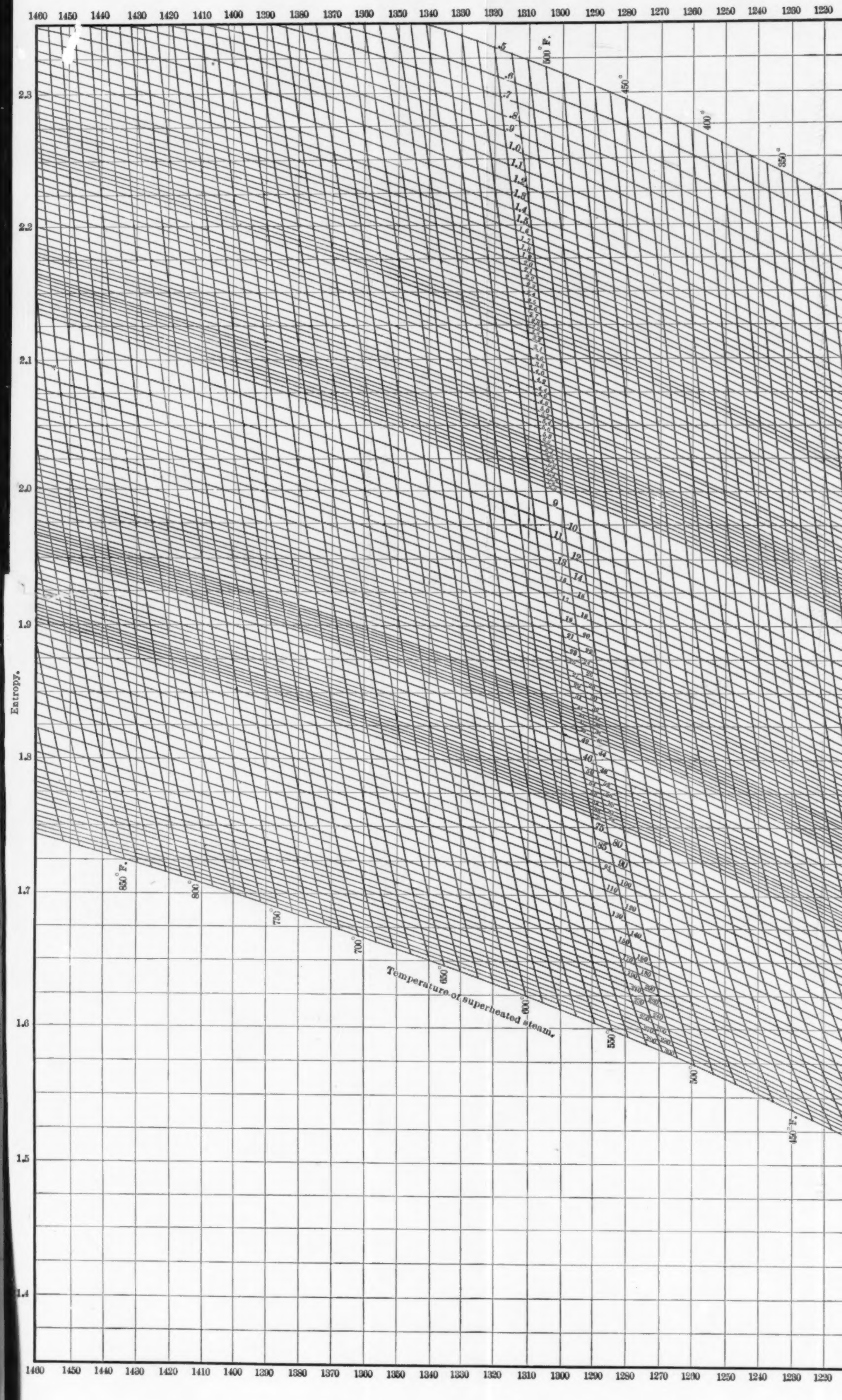


FIG. 20

PLATTED FROM RESULTS OF EXPERIMENT

20

EXPERIMENTS OF 1905–1906.


1460 1450 1440 1430 1420 1410 1400 1390 1380 1370 1360 1350 1340 1330 1320 1310 1300 1290 1280 1270 1260 1250 1240 1230 1220
Entropy.
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
500° F.
450°
400°
350°
850° F.
800°
750°
700°
650°
600°
550°
500°
450° F.
Temperature of superheated steam.

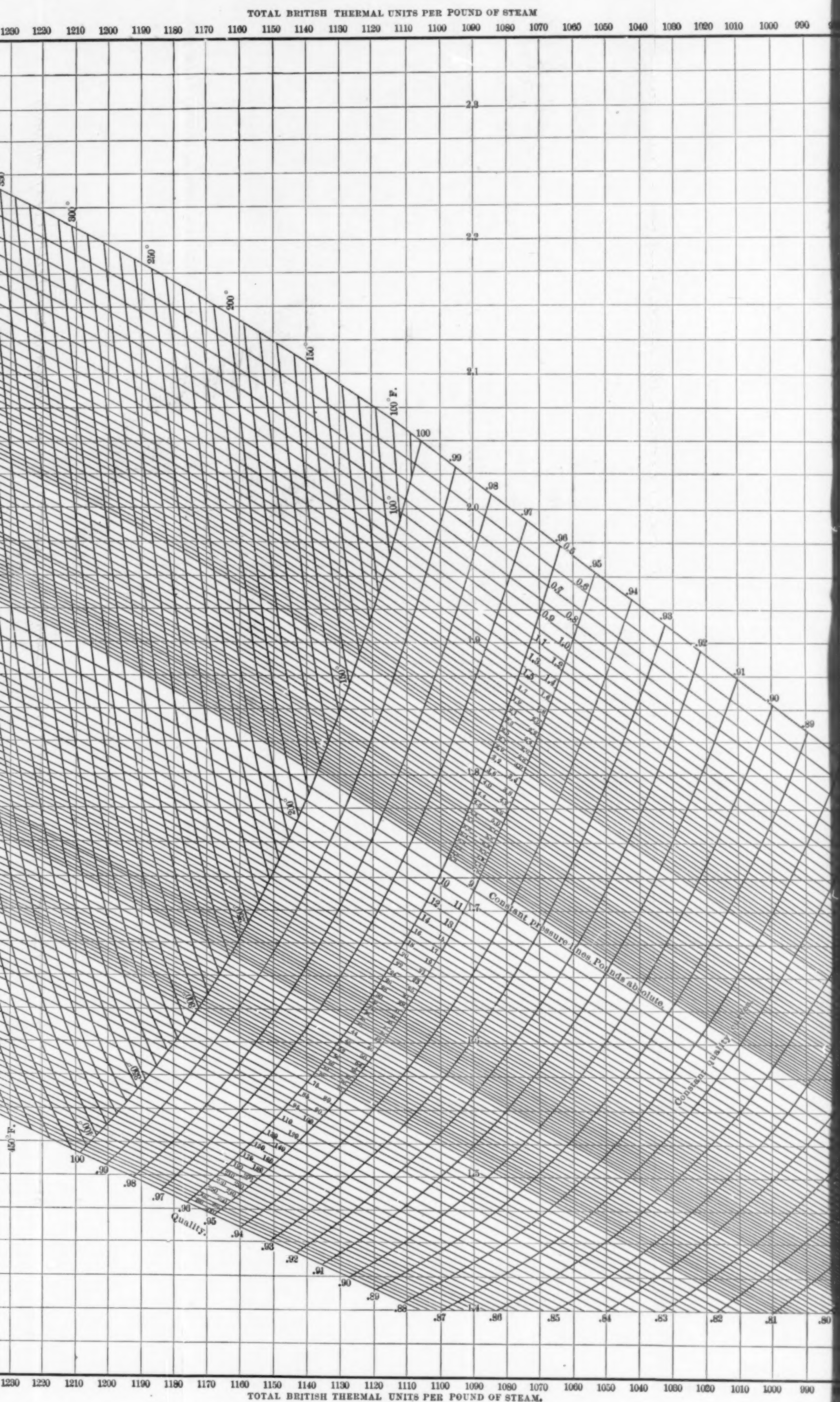

TOTAL BRITISH THERMAL UNITS PER POUND OF STEAM
1230 1220 1210 1200 1190 1180 1170 1160 1150 1140 1130 1120 1110 1100 1090 1080 1070 1060 1050 1040 1030 1020 1010 1000 990
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
300°
250°
200°
150°
100° F.
100
.99
.98
.97
.96
.95
.94
.93
.92
.91
.90
.89
.88
.87
.86
.85
.84
.83
.82
.81
.80
Constant pressure lines Pounds absolute.
Quality.
TOTAL BRITISH THERMAL UNITS PER POUND OF STEAM.

FIG. 21

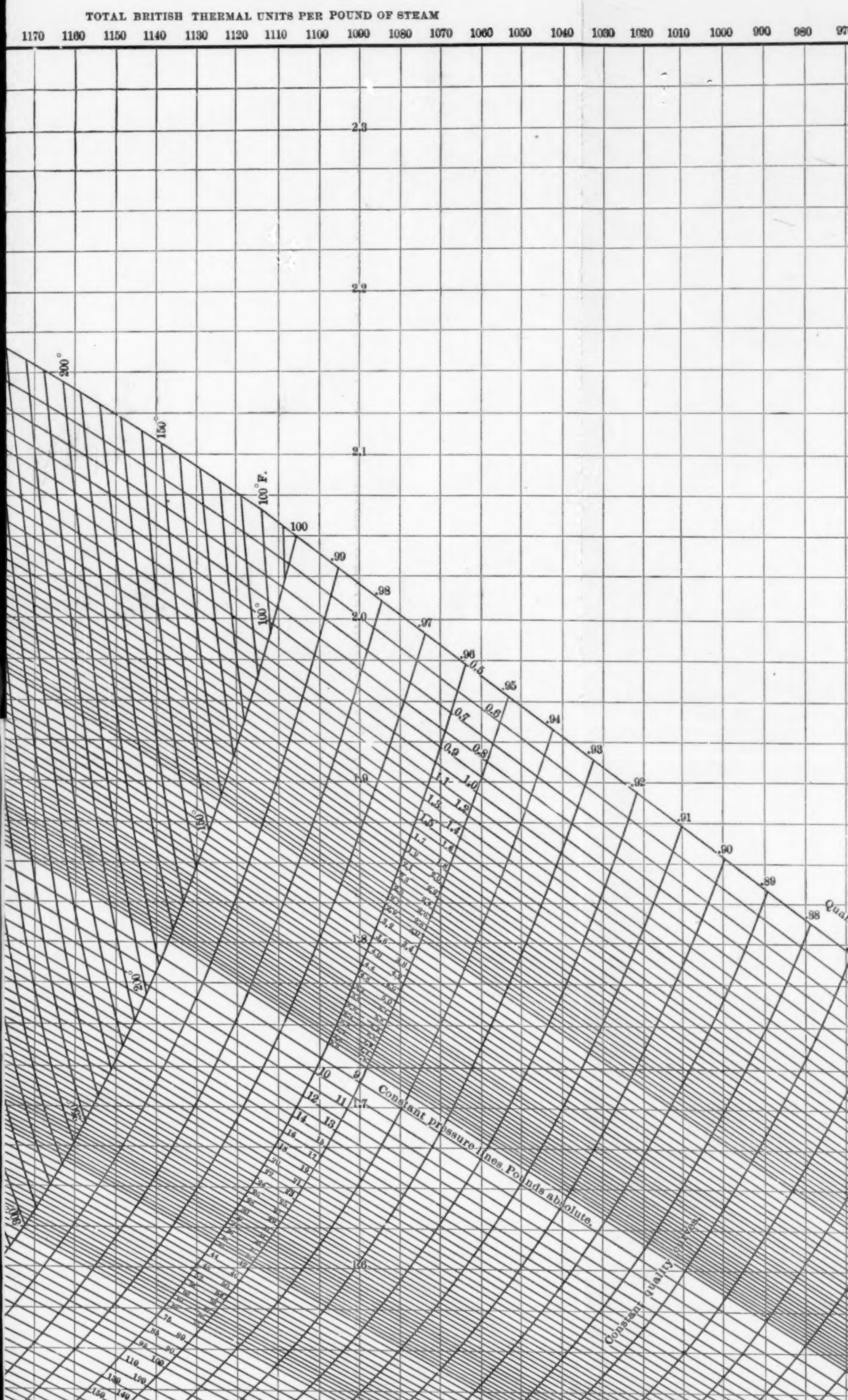

TOTAL BRITISH THERMAL UNITS PER POUND OF STEAM
Constant pressure lines, Pounds absolute.
TOTAL BRITISH THERMAL UNITS PER POUND OF STEAM.

FIG. 21

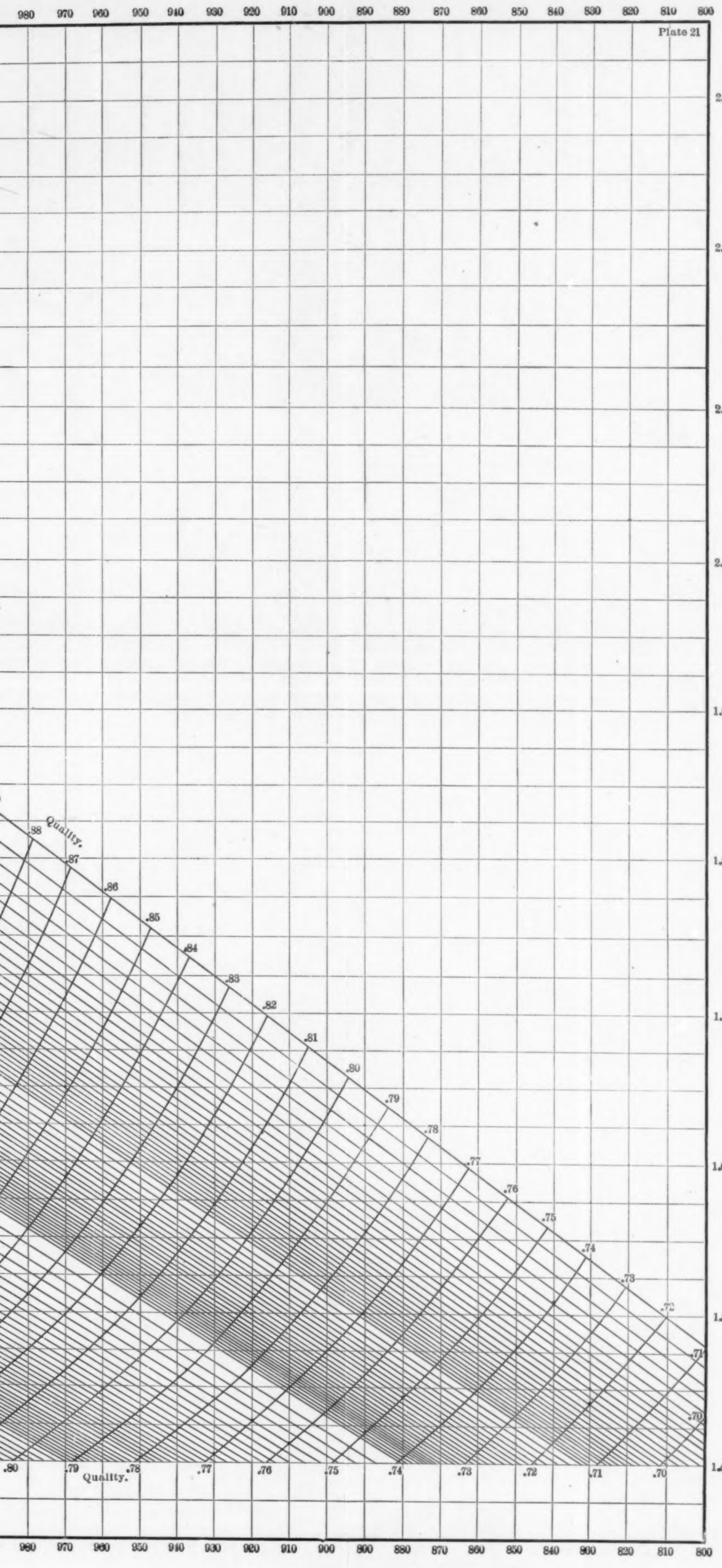


Plate 21
Entropy.
Quality.
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
980 970 960 950 940 930 920 910 900 890 880 870 860 850 840 830 820 810 800
.88 .87 .86 .85 .84 .83 .82 .81 .80 .79 .78 .77 .76 .75 .74 .73 .72 .71 .70

$\frac{E_2}{W_2}$ = Watts req'd to dry and superheat one lb. steam. = ...

$\frac{E_1}{W_1}$ = Watts req'd to dry one lb. steam = ...

$S = \frac{E_2}{W_2} - \frac{E_1}{W_1}$ = Watts req'd to superheat one lb. steam = ...

60 The writer wishes to express his appreciation of the assistance that he has received from a large number of colleagues and workers in allied lines, for without the coöperation of others it would have been impossible to carry to completion the investigation forming the subject of this paper. Particularly, the interest of Mr. E. W. Rice, vice president and chief engineer of the General Electric Company, and the constant interest and assistance given to the work by Dr. W. R. Whitney, director of the research laboratory, General Electric Company, and that of Dr. W. D. Coolidge of the same laboratory have been very largely the sustaining influences throughout the investigation. The apparatus used in the experiments, aside from that furnished by Sibley College, Cornell University, was all loaned by order of the above named officials of the General Electric Company, and the author had frequent occasion to consult with members of the staff of the research laboratory regarding the details of the work.

61 Through the influence of Prof. R. C. Carpenter, the water-tube boiler used in the tests was kindly supplied by the White Automobile Company of Cleveland, and to Professor Carpenter and to Dr. J. S. Shearer of the department of physics, Cornell University, especial thanks are due for their continued interest and assistance in supplying apparatus for the work.

62 The investigation has been made possible by the support and encouragement given by Sibley College, which has supplied everything needed for the work aside from what has already been mentioned as coming from outside sources.

63 The writer has been especially fortunate in having the active assistance of Mr. C. E. Burgoon and Mr. F. J. Short, both men of mechanical and scientific abilities, who were elected to fellowships in Sibley College during the years 1905–1906 and 1906–1907 respectively, and who came prepared by experience obtained in active engineering positions for the purpose of doing advanced research work in mechanical and electrical engineering. Mr. Burgoon's work has already been referred to in the body of the article as of great assistance in develoving the apparatus and methods employed. Mr. Short came into the work when the reconstruction of the entire apparatus was in hand and by most persistent and intelligent attention to

details was very helpful in bringing the apparatus to its present state of completeness and ease of operation. Mr. Short operated the apparatus during the past year 1906–1907 with great skill and care and to his work is largely due the regularity of the results obtained. He has been of great assistance also in the preparation of the curves as presented in this paper.

64 In closing the writer wishes to refer again to the methods used before he began his investigations, because he feels that he owes a debt of gratitude to the men who tried them out, unsatisfactory though they proved to be. They enabled him to begin at a point much farther along than would have been otherwise possible. Particularly of value in this respect was the work carried on through a period of several years in Sibley College under the direction of Professor Carpenter, using first the method of expanding into a throttling calorimeter, then of heating by gas, and lastly, of heating electrically, according to the method first tried by the writer. While all of these methods were discarded by the writer as unreliable, they formed a stepping stone from which he was able to work towards satisfactory results. Those results, therefore, he presents as the fruit not only of his own final method but of all who worked before him.

TABLE 1

ORIGINAL DATA, PLOTTED ON PLATES 1 TO 7 INCLUSIVE

TEST NUMBER	DATE 1907	PRESS. LBS. PER SQ. IN. ABS.	TEMP. OF STEAM LEAVING CAL. CENT.	TEMP. OF STEAM ENTERING CAL. CENT.	RISE OF TEMP. IN CALORIMETER, CENT.	DURATION OF TEST. MINUTES AND SECONDS	LBS. WATER OBTAINED DURING TEST, WHEN E_1 WATTS ARE BEING INTRODUCED	LBS. WATER OBTAINED DURING TEST, WHEN E_2 WATTS ARE BEING INTRODUCED	E_1 WATTS. REQ'D TO DRY W_1 LBS. STEAM PER HR.	E_2 WATTS REQ'D TO DRY AND SUPERHEAT W_2 LBS. STEAM PER HOUR.	POUNDS SUPERHEATED STEAM FLOWING PER HR. $= W_2$	POUNDS DRY STEAM FLOWING PER HOUR. $= W_1$	WATTS	ROOM TEMP. CENT.	CONDENSED STEAM TEMPERATURE, CENT	MICROVOLTS	CORRESPONDING TEMPERATURE CENT.	$\frac{E_2}{W_2}$ = WATTS REQ'D TO DRY AND SUPERHEAT ONE LB. STEAM	$\frac{E_1}{W_1}$ = WATTS REQ'D TO DRY ONE LB. STEAM	$s = \frac{E_2}{W_2} - \frac{E_1}{W_1}$ = WATTS. REQ'D TO SUPERHEAT ONE LB. STEAM
1	8–6	7	80.	80.	0	14–35	3		65.			12.3	65	27	28	4 210	80.		3.4	
2	8–6	7	100.	80.	20	16–15		3		100	11.1		100	27	28	5 300	100.	9.	3.4	5.6
3	8–6	7	120.	80.	40	11–10		2		150	10.7		150	27	28	6 400	120.	14.	3.4	10.6
4	8–6	7	140.	80.	60	11–40		2		198	10.3		198	27	28	7 470	140.	19.2	3.4	15.8
5	8–6	7	160.	80.	80	11–10		2		255	10.7		255	27	28	8 560	160.	23.8	3.4	20.4
6	8–6	7	180.	80.	100	21–0		4		330	11.4		330	27	28	9 660	180.	28.9	3.4	25.5
7	8–6	7	230.	80.	150	21–40		4		465	11.2		465	27	28	12 440	230.	41.6	3.4	38.2
8	7–24	20	109.	109.	0	6–10	3		90.			29.2	90	27	28	5 800	109.		3.1	
9	7–24	20	129.	109.	20	6–40		3		240	27.		240	27	28	6 870	129.	8.9	3.1	5.8
10	7–24	20	149.	109.	40	11–27		5		370	26.2		370	27	28	7 960	149.	14.1	3.1	11.0
11	7–24	20	169.	109.	60	11–30		5		505	26.1		505	27	28	9 060	169.	19.3	3.1	16.2
12	7–24	20	189.	109.	80	11–50		5		610	25.4		610	27	28	10 170	189.	24.	3.1	20.9
13	7–24	20	209.	109.	100	6–18		3		720	24.7		720	27	28	11 270	209.	29.1	3.1	26.
14	7–24	20	259.	109.	150	7–27		3		1010	24.1		1010	27	28	14 060	259.	41.9	3.1	38.8
15	7–24	35	126.	126.	0	5–27	3		155.			33.	155	27	28	6 710	126.		4.7	
16	7–24	35	146.	126.	20	5–40		3		340	31.8		340	27	28	7 800	146.	10.7	4.7	6.
17	7–24	35	166.	126.	40	9–22		5		510	32.		510	27	28	8 900	166.	16.	4.7	11.3
18	7–24	35	186.	126.	60	9–55		5		645	30.3		645	27	28	10 000	186.	21.3	4.7	16.6
19	7–24	35	206.	126.	80	9–55		5		780	30.		780	27	28	11 110	206.	26.	4.7	21.3
20	7–25	35	226.	126.	100	8–30		3		680	21.2		680	27	28	12 210	226.	32.	5.3	26.7
21	7–25	35	126.	126.	0	8–0	3		110			22.5	110	27	28	6 710	126.		5.3	
22	7–25	35	276.	126.	150	14–35		5		920	20.6		920	27	28	15 040	276.	44.6	5.3	39.3
23	7–25	55	141.5	141.5	0	5–6	3		180.			35.3	180	27	28	7 550	141.5		5.4	

TABLE 1 (Continued)

24	7–25	55	161.5	141.5	20	8–40		5		400	34.7		400	27	28	8 650	161.5	11.5	5.4	6.1
25	7–25	55	181.5	141.5	40	8–55		5		570	33.7		570	27	28	9 750	181.5	17.	5.4	11.6
26	7–25	55	201.5	141.5	60	9–0		5		750	33.3		750	27	28	10 850	201.5	22.5	5.4	17.1
27	7–25	55	221.5	141.5	80	5–50		3		850	31.		850	27	28	11 980	221.5	27.5	5.4	22.1
28	7–25	55	241.5	141.5	100	9–30		5		1030	31.6		1030	27	28	13 100	241.5	32.6	5.4	27.2
29	7–25	55	291.5	141.5	150	10–7		5		1350	29.7		1350	27	28	15 910	291.5	45.4	5.4	40.
30	7–26	75	153.	153.	0	12–15	3		225.			14.7	225	27	28	8 180	153.		15.3	
31	7–26	75	173.	153.	20	12–30		3		310	14.4		310	27	28	9 300	173.	21.5	15.3	6.2
32	7–26	75	193.	153.	40	12–50		3		380	14.		380	27	28	10 400	193.	27.1	15.3	11.8
33	7–26	75	213.	153.	60	13–15		3		440	13.6		440	27	28	11 500	213.	32.3	15.3	17.
34	7–26	75	233.	153.	80	13–27		3		500	13.3		500	27	28	12 600	233.	37.7	15.3	22.4
35	7–26	75	253.	153.	100	13–35		3		570	13.2		570	27	28	13 740	253.	43.2	15.3	27.9
36	7–26	75	303.	153.	150	14–0		3		715	12.8		715	27	28	16 570	303.	55.8	15.3	40.5
37	7–26	115	170.	170.	0	8–6	3		230.			22.3	230	27	28	9 110	170.		10.3	
38	7–26	115	170.	170.	0	8–6	3		255.			22.3	255	27	28	9 110	170.		11.4	
39	7–26	115	190.	170.	20	8–6		3		370		22.3	370	27	28	10 210	190.	16.6	10.3	6.3
40	7–26	115	210.	170.	40	8–36		3	490.			20.9	490	27	28	11 330	210.	23.5	11.4	12.1
41	7–26	115	230.	170.	60	9–5		3		570	19.8		570	27	28	12 440	230.	28.8	11.4	17.4
42	7–26	115	250.	170.	80	9–0		3		680	19.7		680	27	28	13 560	250.	34.6	11.4	23.2
43	7–26	115	210.	170.	100	9–0		3		790	19.7		790	27	28	14 700	270.	40.	11.4	28.6
44	7–26	115	320.	170.	150	9–35		3		990	18.8		990	27	28	17 540	320.	52.7	11.4	41.3
45	7–31	165	185.	185.	0	15–30	3		370.			11.6	370	27	28	9 950	185.		31.9	
46	7–31	165	185.	185.	0	14–30	3		385.			12.4	385	27	28	9 950	185.		31.	
47	7–31	165	205.	185.	20	15–0		3		450	12.		450	27	28	11 050	205.	37.5	31.	6.5
48	7–31	165	225.	185.	40	15–30		3		503	11.6		503	27	28	12 160	225.	43.4	31.	12.4
49	7–31	165	245.	185.	60	15–34		3		570	11.35		570	27	28	13 270	245.	50.2	32.	18.2
50	7–31	165	265.	185.	80	16–30		3		610	10.9		610	27	28	14 410	265.	56.	31.9	24.1
51	7–31	165	285.	185.	100	16–40		3		665	10.8		665	27	28	15 550	285.	61.5	31.9	29.6
52	7–31	165	335.	185.	150	17–30		3		760	10.3		760	27	28	18 400	335.	73.8	31.9	41.9
53	8–1	215	197.5	197.5	0	11–10	3		190.			16.2	190	27	28	10 640	197.5		11.8	
54	8–1	215	217.5	197.5	20	11–50		3		280	15.2		280	27	28	11 750	217.5	18.4	11.8	6.6
55	8–1	215	237.5	197.5	40	12–0		3		360	15.		360	27	28	12 860	237.5	24.	11.8	12.2
56	8–1	215	257.5	197.5	60	12–25		3		435	14.5		435	27	28	14 000	257.5	30.	11.8	18.2
57	8–1	215	277.5	197.5	80	12–45		3		505	14.1		505	27	28	15 130	277.5	35.8	11.8	24.
58	8–1	215	297.5	197.5	100	13–15		3		565	13.6		565	27	28	16 250	297.5	41.6	11.8	29.8
59	8–1	215	347.5	197.5	150	14–10		3		690	12.7		690	27	28	19 130	347.5	54.3	11.8	42.5
60	8–1	300	214.	214.	0	8–50	3		310.			20.4	310	27	28	11 550	214.		15.2	

TABLE 1 (Continued)

61	8–1	300	234.	214.	20	9–10		3		430	19.7		430	27	28	12 660	234.	21.9	15.2	6.7
62	8–1	300	254.	214.	40	9–5		3		550	19.8		550	27	28	13 790	254.	27.8	15.2	12.6
63	8–1	300	274.	214.	60	9–20		3		650	19.3		650	27	28	14 930	274.	33.7	15.2	18.5
64	8–1	300	294.	214.	80	9–30		3		750	19.		750	27	28	16 050	294.	39.5	15.2	24.3
65	8–1	300	314.	214.	100	9–50		3		830	18.3		830	27	28	17 200	314.	45.3	15.2	30.1
66	8–3	300	214.	214.	0	10–30	3		370.			17.2	370	27	28	11 550	214.		21.5	
67	8–3	300	364.	214.	150	20–20		5		950	14.8		950	27	28	20 090	364.	64.5	21.5	43.
68	8–5	500	242.	242.	0	6–55			415			26.1	415	27	28	13 100	242.		16.	
69	8–3	500	242.	242.	0	10–30	5		355.			26.	355	27	28	13 100	242.		13.6	
70	8–3	500	242.	242.	0	6–55			420.			26.	420	27	28	13 100	242.		16.3	
71	8–5	500	242.	242.	0	10–55			360.			27.5	360	27	28	13 100	242.		13.	
72	8–5	500	262.	242.	20	6–45				530	26.7		530	27	28	14 240	262.	9.8	13.	6.8
73	8–3	500	262.	242.	20	7–0				520	25.7		520	27	28	14 250	262.	20.2	13.6	6.6
74	8–3	500	282.	242.	40	7–0				690	25.7		690	27	28	15 370	282.	26.8	13.6	13.2
75	8–5	500	282.	242.	40	6–45				700	26.7		700	27	28	15 370	282.	26.2	13.	13.2
76	8–3	500	302.	242.	60	7–12				880	25.		880	27	28	16 520	302.	35.2	16.3	18.9
77	8–5	500	322.	242.	80	7–6				1030	25.4		1030	27	28	17 650	322.	40.6	16.	24.6
78	8–5	500	342.	242.	100	7–30				1120	24.		1120	27	28	18 810	342.	46.7	16.	30.7
79	8–5	500	392.	242.	150	7–45				1400	23.3		1400	27	28	21 730	392.	60.2	16.	44.2
80	10–14	20	109.	109.	0	12–30	3		120.			14.4	120	28	21	5 800	109.		8.33	
81	10–14	20	119.	109.	10	12–30		3		165	14.4		165	28	21	6 330	119.	11.43	8.33	3.1
82	10–15	40	130.5	130.5	0	10–53	5		157.			27.6	157	28	21	6 950	130.5		5.68	
83	10–15	40	140.5	130.5	10	11–5		5		240	27.		240	28	21	7 500	140.5	8.9	5.68	3.22
84	10–15	40	130.5	130.5	0	10–53	5		160.			27.6	160	28	21	6 950	130.5		5.8	
85	10–15	40	140.5	130.5	10	10–55		5		245	27.5		245	28	21	7 500	140.5	8.98	5.8	3.18
86	10–15	60	145.	145.	0	7–47	5		205.			38.5	205	28	21	7 755	145.		5.33	
87	10–15	60	155.	145.	10	7–47		5		328	38.5		328	28	21	8 300	155.	8.53	5.33	3.2
88	10–15	100	164.	164.	0	4–50	5		280.			62.	280	28	21	8 780	164.		4.51	
89	10–15	100	174.	164.	10	4–50		5		490	62.		490	28	21	9 340	174.	7.9	4.51	3.39
90	10–15	250	205.	205.	0	5–4	5		310.			59.3	310	28	21	11 050	205.		5.23	
91	10–15	250	215.	205.	10	5–7		5		515	58.7		515	28	21	11 600	215.	8.77	5.23	3.54
92	10–15	400	229.	229.	0	6–54	5		160.			43.5	160	28	21	12 380	229.		3.68	
93	10–15	400	239.	229.	10	7–0		5		310	42.8		310	28	21	12 940	239.	7.24	3.68	3.56

DISCUSSION

A HIGH SPEED ELEVATOR

By Charles R. Pratt, Published in October Proceedings

Mr. J. W. Mabbs[1] It seems to me that the elevator under consideration is a step in the right direction. It undoubtedly adds greatly to the safety of an elevator which by many is considered unsafe.

2 I want to present an elevator that is pronounced by competent experts to be the safest elevator in existence. Safety is undoubtedly the greatest consideration in any elevator; it should be the first consideration, although recently it seems as though some people had departed from this doctrine and had made the matter of safety subservient to other things.

3 The elevator shown in Fig. 1 was designed at a time when there was nothing in the electrical line that could compete with a first class hydraulic elevator or that was satisfactory to the engineering fraternity or public at large.

4 It was desirable to have but one kind of power in a building, consequently there was the demand for a satisfactory electric elevator. The drum machine, the best at the time, was restricted to a speed of 350 feet per minute; had numerous defects; was not a safe machine; was generally unsatisfactory and especially so for high office buildings.

5 The first machine as it is shown here was installed in the Chicago Board of Trade building five years ago, and up to the present time has run about 25 000 miles at an expense for repairs and some changes of $432. This includes everything pertaining to an elevator; the signals, lights, gates, hoisting ropes, electric cables, the machine and controller. In other words, the maintenance of this elevator for repairs of every description was about $86 a year. The speed of this car is from 575 to 600 feet per minute, giving absolutely satisfactory service in a building whose requirements were pronounced by one of your most distinguished members, when he was installing electric

[1] Chief Engineer of the Board of Trade, Chicago.

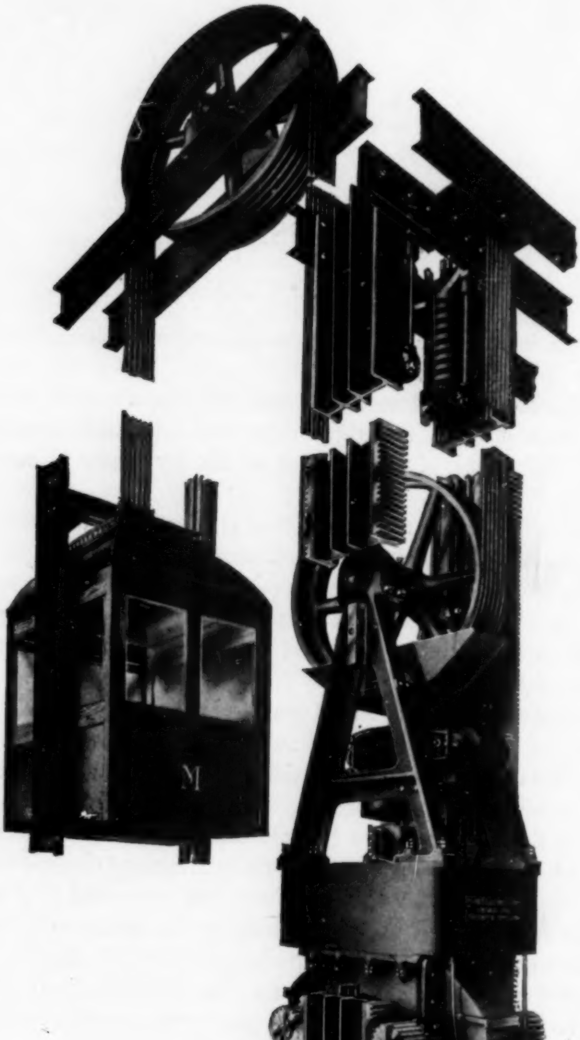


FIG. 1

elevators in it, to be the severest in the United States. After three years of uninterrupted service of the first Mabbs machine, the electric machines referred to above which had proved extremely costly both in operation and repairs and very unsatisfactory generally, were replaced by four Mabbs machines shown in Fig. 2. This view shows the machines in the basement, at the bottom of travel, when the cars are at the top; it also clearly shows the pneumatic buffers which are an absolute limit stop.

6 The principle of this elevator is that the machine constitutes the counter balance of the car, and is the only counter weight. The cables are arranged so the machine is geared two to one and when the machine ascends the car descends, and vice versa.

7 Fig. 3 gives an idea of the construction and design of the machine. The machine has a vertical armature and shaft, upon which are mounted, in order, the brake pulley, upper bearing, commutator, armature, coupling, worm, lower bearing, and roller thrust. The armature is keyed rigidly to the shaft and is connected to the worm, which is really a sleeve on the shaft, by means of the coupling shown. This is arranged so as to permit of the armature being rotated for the purpose of smoothing up the commutator, etc., without operating the gearing.

8 The worm drives the two worm wheels, which are mounted on the two horizontal shafts, and on these shafts are four pinions which engage the four vertical racks which in turn are mounted on cast iron columns, up and down which the motor operates.

9 The current is carried to the armature by trolleys mounted on porcelain blocks on the inner face of one of the beams. One set of the trolley brushes is shown in Fig. 3. They are made with a superabundance of wearing and contact surface, and after five years there are no burned spots on the trolley.

10 Fig. 4 shows the arrangement of the flexible cables which are put up in duplicate and carry the circuits for the fields brake *solenoid*, and slack cable device.

11 Fig. 5 shows the detail of the lower pneumatic buffer, the upper buffers are clearly shown in Fig. 3. These buffers are designed with sufficient capacity to take care of the momentum of the machine when traveling at full speed, plus the full power of the motor.

12 The motor of this machine is specially designed. In the first machine it was armature controlled; in the last four, field controlled. The lower part of the machine (Fig. 3) is an oil chamber which is filled with oil to a point just below the horizontal shafts. All parts of the machine are automatically lubricated with the exception of

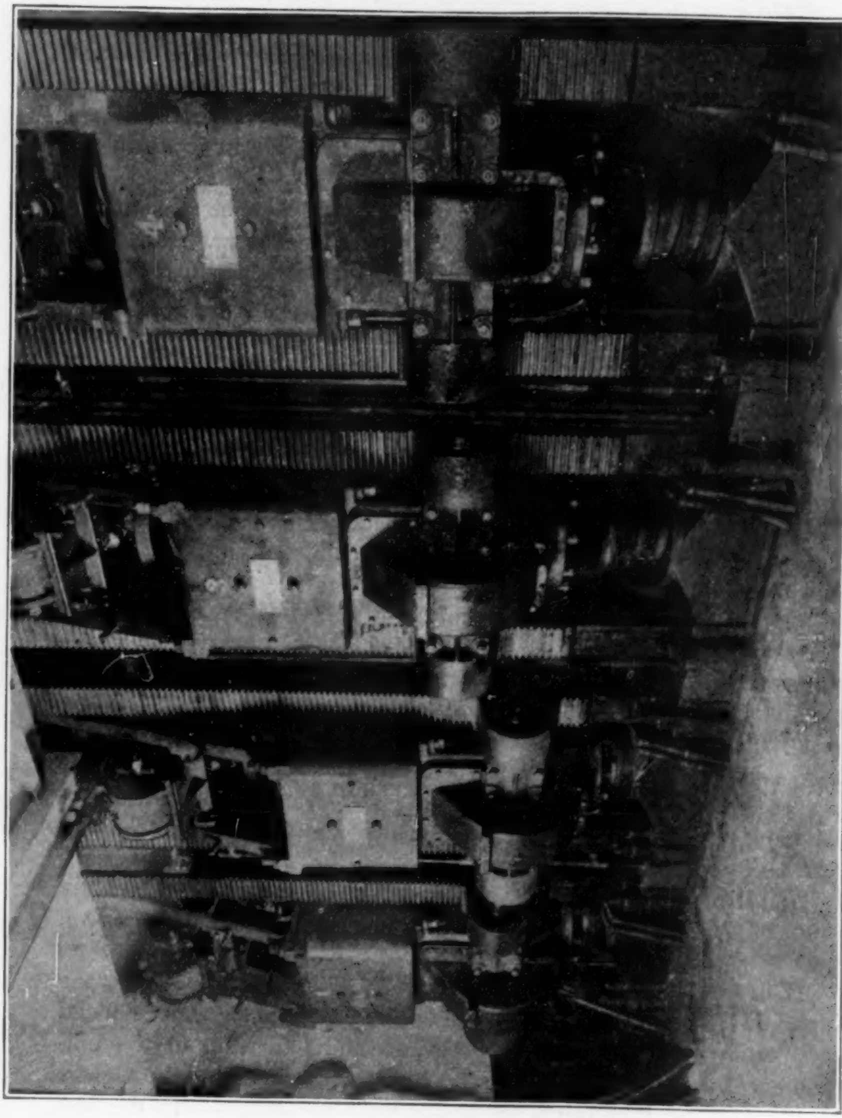
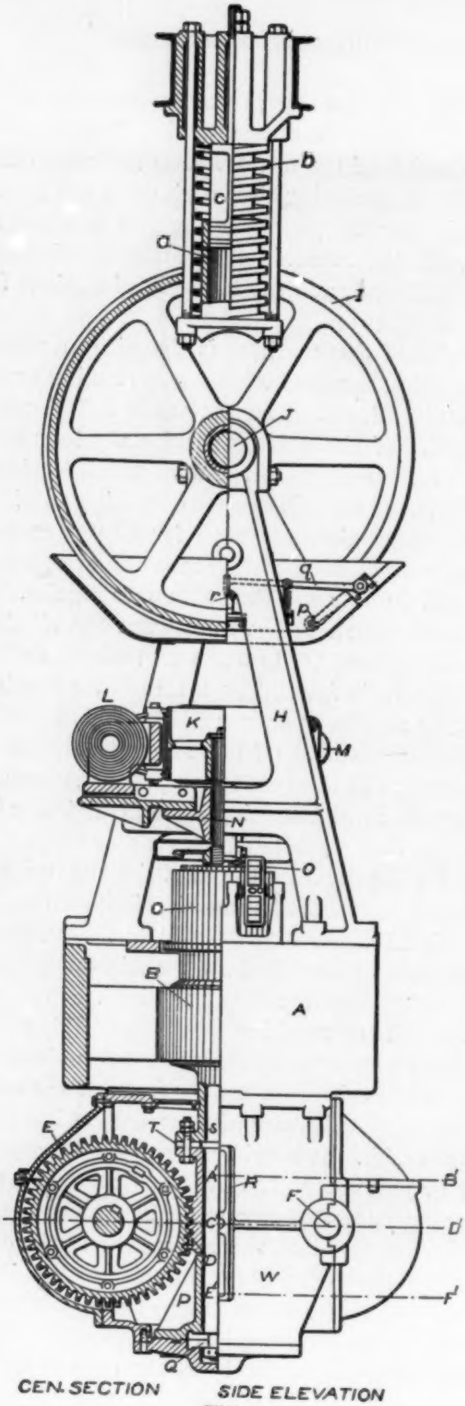


FIG. 2

the upper bearing and the idler; these are supplied with grease cups and require attention about once a week. This chamber being filled with oil, the rotation of the worm wheels and worm lubricate every part of it perfectly, including the bearings of the horizontal shafts. The first machine ran $2\frac{1}{2}$ years on the first charge of oil without attention. The last four machines have now been in nearly two years without *changing* the oil, and the total bill of expense for lubrication is $6.

13 The service of this machine is shown by a test made on the first one, when doing regular business and running express, stopping at five out of nine floors. The car made 547 round trips in 540 minutes. The life of the cables is unusually long as shown by the record of the first machine. After five years service and making 25 000 car miles, they are still in good condition and it is the opinion of the inspectors that they are good for 50 per cent more service. The design and construction of this machine are such as to make it most reliable and durable and thus eliminate repairs. After 25 000 miles of car travel the racks have not worn out all the tools marks, and the teeth of the phosphor bronze worm wheels are hardly polished all the way across their face. The total bill for repairs for the four machines (Fig. 4) for one year was $318. This includes everything pertaining to the elevators. Of this amount only $83 was spent on the machine proper; $43 was spent for repairing an armature that was damaged by a wire band becoming loose at night, leaving $40 as the total repair bill on four machines for a year, or $10 per year per elevator, the balance being spent on the cars, signal gates, controllers, etc.

14 The great feature of this machine is its safety, which should be the first consideration in any elevator. Automatic stops are placed at both ends of travel of the machine which slow down the machine, cut off the current and set the brake, in case the operator fails to do so, and if the machine goes beyond this point it trips the main circuit breaker and cuts off the current from both controller and machine and beyond this again are the buffers, or mechanical stops, which are sufficient to take care of the machine in case the operator and all automatics fail. It is evident from this arrangement that the car can never be jerked into the overhead work and pull the cables out of the car, as has often happened in other types of elevators; neither can it be dropped into the basement and the counter weights pulled down upon the car, a most common and serious accident in other elevators. A greater strain can never be put upon these cables than the load in the car. A push button is placed in the car whereby the main circuit breaker can be instantly tripped by the operator,


b
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CEN. SECTION
SIDE ELEVATION

FIG. 3

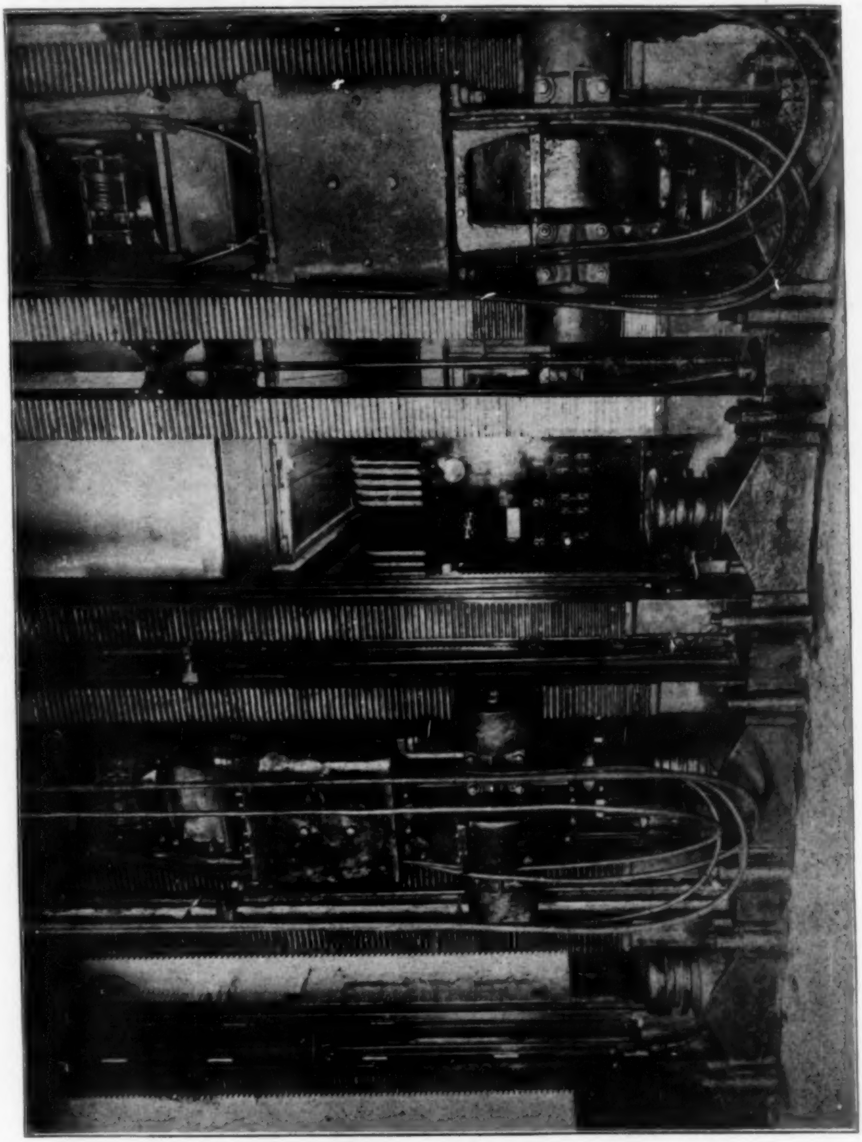
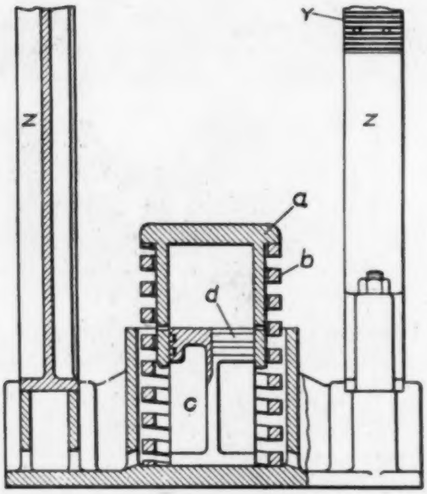


FIG. 4

shutting off the current from both the controller and machine. This is for use in case of disarrangement of the car box of the controller. This principle of the machine and these arrangements make it the safest electric elevator in existence. All the parts of these machines are accessible when the machines are at the lower end of travel and are easily and quickly taken apart and put together.

15 I have recently made some improvements in the first machine, changing its old spring buffers to oil buffers, and I find the oil buffers are a decided improvement over the pneumatic, as they have a greater capacity and *no recoil*, the objectionable feature of the pneumatic buffer. The speed of the machines I have already installed,



BEDPLATE & LOWER BUFFER

FIG. 5

range from 540 to 600 feet per minute, but a much greater speed can be given, if desired, and safely controlled. In the case of very high office buildings, such as are being erected in New York I could safely give them a speed of a thousand feet per minute. This elevator is *particularly* adapted for extremely high buildings, there being no additional complications in its construction or operation in the highest buildings over those of ordinary height. The operation and control of this elevator is pronounced by all who have ridden in it to be *ideal*, its start and stop being smooth and at the same time very quick, it being possible to reverse this car when traveling at full speed without a perceptible pause and without the slightest shock or jar.

These features mean increased and satisfactory elevator service, and make it particularly adapted for service where ladies are patrons.

16 The space occupied by these machines, including clearance is 52 by 42 inches, but I am working on a new design which will bring the width of this shaft down to 20 by 24 inches.

17 The racks and pinions are all cut steel and when they are properly cut and erected they run noiselessly. The most noise from these machines is the hum of the commutator.

18 The current consumption of the first machine, running express for a period of over four years was 3.44 kw. per car mile, there being conditions and days when it dropped below 3 kw. per car mile. The four machines shown in Fig. 2 which run locally operating much larger and heavier cars and carrying heavier loads showed an average current consumption for a period of 76 weeks of 3.5 kw. per car mile. As I said before, the service is unusual, and is undoubtedly the severest required of any elevators in this country.

MR. C. W. NAYLOR[1] The ordinary worm gear drum type of electric machine has several serious defects, even sources of danger.

2 The brake wheel is toc small in diameter; the brake, when electric, either for set or release is too sudden and will pull lifting cables out of clevises in two years or less; besides it makes too sudden a stop with all the disagreeable accompaniments, in spite of the fact that it is supposed to be arranged to go into action at some proper moment that will avoid the occurrence of that fault.

3 In practice it is impossible to adjust such a brake so that it will set alike for different speeds, loads, and temperatures in the machine.

4 The complicated wiring in both field and armature for a magnet control machine is a source of worry and confusion to the care taker and is sometimes carried to such an extreme that it is not absolutely certain in which direction a car is going to travel when the controller handle is thrown from the central or neutral position.

5 A cross, or a ground, or a short circuit, anywhere in the wiring will often lead to serious and not easily understood complications and uncertainty as to just what the machine is going to do when started.

6 This type of machine is limited to lifts of 200 feet or less, although there are fairly successful installations with somewhat longer lifts. It is not suited for speeds of over 350 or 400 feet per minute.

[1] Chief Engineer, Marshall Field, Chicago.

7 If the starting acceleration is not too great the machine can be very economical of current if properly counter-balanced.

8 In regard to the overhead traction machine to be used in your Singer building Mr. Pratt's suggestion for an auxiliary motor driven worm in place of the brake band is not so clear to the reader but that he might ask *will it synchronize with* the main motor. I am curious to know just how the system would work out in practice.

9 Is it not an attempt to get back to the worm gear drive on the elimination of which we have been congratulating ourselves?

10 The clanking pendant balance chains must be eliminated from the high lift and high speed elevator, from the open hatchway at least if not for good.

11 The quick setting car dog must also be relegated to the scrap pile.

MR. R. P. BOLTON The electrical traction elevator, to which this paper directs attention, is the logical outcome of a process of inventive deductions which has gradually brought together the simple elements of a slow-running motor, and a four-bend cable drive of sufficient surface and number of ropes to ensure a frictional hold under starting resistances. The course of invention, in order to reach this simple result, has had to pass through various stages of complication, each of which introduced into the electrical method of operation some disadvantageous or insecure elements.

2 The ingenious screw-and-ball nut machine, designed by the author of this paper, was an attempt to attain high speed by imitating the operation of the expanding sheave motion of the hydraulic piston or ram, while the drum machine, which has become so very widely used for moderate speeds, is an adaptation of the high speed motor to the winding drum, by the intermediary of a reducing gear, generally in the form of a worm and wheel. These were followed by several forms of friction drives, highly ingenious but dubious, and all appear to have assumed, as a fixedly determined element, a high rotative speed of the electrical motor.

3 The author scarcely gives himself sufficient credit for his own share in directing the course of this now important development of electrical operation, for it was his experiments, to which he so briefly refers, which first made it clear that such a method of hoisting could be not only practically accomplished but successfully controlled at high speeds.

4 But the development of this method of operation, combined with the slow running motor lay dormant for some years, awaiting

the introduction to it of the means of positive arrest of its unlimited motion of car and counterbalance. To Mr. Thos. E. Brown the credit is due for the perception of the necessity, and for its offspring in the form of the hydraulic buffer attached to car and counterbalance.

5 The combination presents the elements of security to a superior degree. The ever present danger with the drum type of over running the car or the counterweight into the head beams and the equally present danger of misplaced ropes are eliminated, as well as the complicative double sets of counterweights, ropes and sheaves for the back drum and the car counter-balances.

6 The machine thus developed bears some general likeness to the hydraulic plunger machine, with the essential difference, however, that its moving mass is of less amount, and its balance of parts equal at all parts of its travel. Thus far we find the author in full sympathy with the development, but in Par. 11, with a very sudden reversal, he switches on to another track and confronts us with an apparent course of hidden dangers, for which he proceeds to propose a device as a remedy.

7 The fact that a friction brake is not positive in its action is incontrovertible, but to a considerable extent that very element is conducive to a secure operation of the elevator. Any means of arresting the moving mass in an elevator, must be so regulated as to bring about a gradual retardation, otherwise the arrest, brought about with a positive appliance such as that which is proposed by the author, may introduce extreme strains into the working appliances. Stoppages of a sudden nature, it may well be remembered, are productive of the same effects upon the living load as a fall in one direction, or as involuntary ascent in the other direction.

8 The instantaneous arrest of a car descending at a speed of 960 feet per minute produces the same effect upon the passenger as a free fall to the ground of four feet, and the sudden stoppage of a car at the same speed in ascending, would leave the passengers to continue their travel and return to the car floor by gravity.

9 Any rigid appliance for arrest, therefore, requires careful provision for its relief in case of too sudden an application, as is done in the hydraulic machine, where the cutting off of the exit of water would otherwise result in an instantaneous and positive stoppage were it not for the usual relief valve.

10 It is probable therefore, that the synchronous worm and wheel device, to the merits of which the rest of this paper is devoted may eventually be found to be necessarily connected to the hoisting

shaft by some means affording flexibility, whereby in case of its too sudden stoppage of the moving mass, a certain relief motion may be permitted. Otherwise entire dependence for security of the elevator will be transferred from the electrical controlled valve to the electrical control of the secondary motor, which appears to be merely an exchange of liabilities.

11 It will be very interesting to learn the results of the author's experiments with this method of control in actual practice. Until this demonstration it will be well to withhold final judgment upon the frictional brake, which, as at present applied to this type of machine is a well tried apparatus, which, with the particular care by which it and all other parts of high class passenger elevators are attended, is not to be considered as entirely lacking in the element of safety. Further, the frictional brake, in its later development in the traction machine, is supplemented by electrical control of the powerful torque of the motor.

12 The brake operation being preceded by the gradual cutting out of the motive circuit, and by the stoppage of the motor by short circuiting the armature, it does not follow therefore that the frictional brake has in stopping the moving mass any severe duty to perform. As regards the reverse or starting operation, the interrelated operation of applying current to the motor and to the solenoid which pulls off the brake, is facilitated by the gradual cutting in of current in the armature circuit, and is not, as would appear from the author's remarks, a sudden full starting current applied to the armature prior to the release of the brake.

13 I am sorry that in a paper which is to enter this Society's records the author should so loosely employ several important terms and phrases. I think it would be well if a definition could be made of the term safety. It is evidently in itself lacking in comprehensiveness, since we find various adjectives utilized to express its relative character, such as "entire," "complete," "absolute," and, in the author's last words of the paper "perfect safety."

14 I regard the condition under which elevator apparatus should be found as better described by the word "security." The difference may perhaps be illustrated by the practice of bankers, who may feel considerable "safety" in loaning to certain persons, but are nevertheless customarily cautious enough to demand "security" in addition to safety.

15 I regret to observe too, that in Par. 17, the writer used the phrase so constantly misused and productive of so much misunderstanding on the part of non-technical persons, in alleging that the

car deprived of co-operation between motor and brake, "falls free" to the bottom of the hoistway. Such a term could be applicable only to such conditions as the entire separation from the car from all its supporting, or retarding, or "safety" appliances. In this case, it is particularly misleading, since with this particular form of machine, the power of motor-control and reversal would still remain in the hands of the operator, while the descent of the car even under such conditions as described, would not be "free," being retarded by the inertia of the counterweight, ropes, rotating sheaves and rotor, to say nothing of the Pratt or other "safety" speed-controlling devices with which we may assume it to be equipped.

16 The author's point of view of the traction machine seems to be mainly that which deals with its powers of retardation of the moving material, and he has not dwelt so appreciatively as he might upon the feature of the important powers of acceleration which this type of machine affords, due to the large size of the motor, and to the elimination of much of the frictional resistance of operating parts.

17 The same features afford a capacity for the operation of maximum loads at maximum speeds and the combined result is the most effective element in the direction of traffic capacity, affecting beneficially the time consumption on the lifting side of the operation of elevator travel.

18 It is interesting, though a little amusing, to learn of the elaborate preparation taken prior to deciding upon this, the only practicable form of machine, for the tower portion of the Metropolitan building. One may be pardoned for wondering why it was necessary to take "over 1500 pages of testimony" regarding a matter in which elementary knowledge of elevator conditions must have eliminated practically every debatable element.

19 We do not learn if the same extent of attention was paid in the Singer building to this subject when the same decision was priorily reached, nor are we told whether the far more important matter of the extent and character of the elevator service to be provided in the case of either building, not merely by the machines, but by the cars, travels, floors and work which have been connected with them, received any attention at all.

20 It is, however, asserted that time was actually consumed in the consideration of direct plunger machines for the installation first referred to above, and presumably this subject forms some part of the fifteen hundred pages of testimony which could well have been spared. The position occupied by the passengers in such an apparatus would be comparable to the traditional fly upon the flywheel,

without the ability, however, of the fly, to utilize wings in case of necessity.

21 With a loaded car at top of such a run, upwards of 350 feet of plunger would be hanging from the bottom of the car, and the living load would form but about 5 per cent of the total mass in motion.

22 The published accounts of one of the tower buildings afford some information as to what number of elevators are to be installed therein and under what circumstances their duty is to be performed. Running express to the thirteenth floor above the ground floor, the elevators are to become way cars for from 22 to 28 floors above that point, a number of floors which general practice has shown to be excessive, even when locally served without the delay of the express run.

23 Moreover the convenient operation of a bank of cars of which one is extended considerably in travel beyond the others, results in delaying the time service of all. For so long a run, the cars which are described as being 25 square feet in area, are inadequate in size, and have insufficient margin of capacity to handle the minimum rate of traffic.

24 I figure that, with a sacrifice of but one per cent of the net rentable area, an adequate number of elevators could have been installed in the Singer tower, the result of which would have been to place the average service of the tower portion, ten floors nearer the street, a result which an authority in mortgage values tells me, would add several hundred thousand dollars to the real estate value of the property.

25 The speed of 600 feet per minute, which it is stated is demanded for these machines, is, by the circumstances of the service to which they are to be applied, of small relative value, since the service imposed upon them calls for local stops of such frequency that the maximum speed can be developed advantageously only on the comparatively short express run.

26 The superior power of the traction type of machine to accelerate maximum loads is the saving element in the adverse conditions of service to which they are to be applied.

27 With due allowance for this element it can be shown that to extract the entire tenants from the tower in case of panic or other necessity, about 40 minutes time would be required, whereas, with a properly proportioned service the same could be effected in 18½ minutes.

28 This is, I consider, a test which should be applied to the sufficiency of any elevator installation.

29 It is unfortunate that the opportunity, afforded by these high towers, of demonstrating the real capabilities of modern elevators, seems to have been so far missed, as to leave the subject very much where it has been left by other new types of building, in a very tangled and indefinite condition, and the very elaborations devoted to the decisions on the subject of the type of elevator machine, however proper the conclusions thereby attained, may contribute to very indeterminate conclusions as regards the practicable value of tower buildings, which with proper provisions, as to the service to which these machines are to be applied, might take on a different complexion.

30 I am shortly to publish the results of my work on this part of the subject of elevators, and shall hope to have an opportunity at a later date of explaining to our members the limitations and operating conditions of elevators and their due and proportionate relations to the building which they serve.

Mr. G. A. Orrok The author is to be congratulated on the ingenious and efficient means he uses to supersede the spring actuated friction brake, thus increasing the safety and reliability of the traction elevator machine.

2 Elevator accidents, while comparatively few, are yet common enough to make us welcome any improvements tending to greater safety, better control and reliability. The drum type of elevator machine, under the influence of the ever increasing height of our modern office building and the necessity of maintaining a comparatively high speed of car travel, has developed limitations and is given place in later installations to the traction type as the best machine for electric elevator service.

3 Many people have believed that the surest way to have safe elevators was to install the plunger type, putting up with the increased cost of operation to secure the appearance of safety which the presence of the plunger affords. This is a fairly good proposition when there is a steam plant of some size in the building, but with the power service of the building furnished electrically from a central station, now the usual practice, the electric pump and hydraulic elevator is at a decided disadvantage as compared with the electric elevator.

4 The introduction of the traction elevator is such a step in advance of the drum type that it will be used more often for high speed work than any other. But what about existing plants with plunger elevators whose owners have to maintain a steam plant or use electric pumps, in either case not getting the economy which they should obtain? This type of elevator is mainly chosen on account of its

safety in operation and when installed, is not being replaced by other types. For such cases as these a member of the Society, Mr. Thos. E. Murray, has devised a combination of the two types, putting a traction machine on the counterweight rope of the existing plunger elevator, taking off the hydraulic hand control and substituting a tank for the pressure water supply, leaving of the hydraulic arrangements only

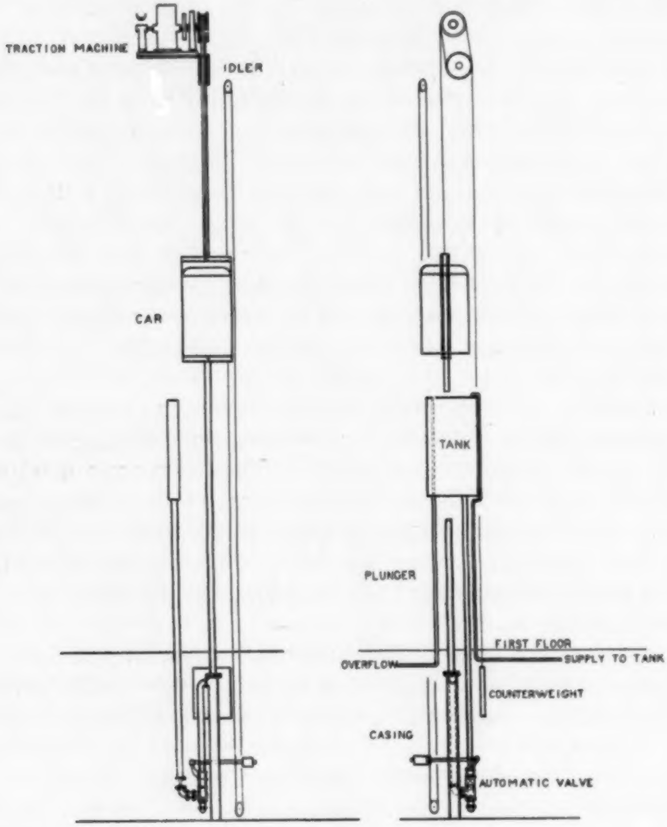


FIG. 1

the automatic top and bottom stops. The plunger elevator now becomes an electrically driven traction elevator with a plunger safety; is safe to a greater degree than the plunger, and is also fairly efficient. The slide shows the arrangement of the experimental machine as at present installed in the office building of The New York Edison Company.

5 The elevator, as outlined above, consists of a car suspended from cables which pass over and partly around the sheaves of an ordinary traction machine, a counterweight being attached to the opposite ends of the cable.

6 The car is also equipped with a plunger running in a casing which is connected to a water supply of practically constant head. The car is operated by an electric control, in the same manner as a traction machine, and brought to rest by an electrically controlled

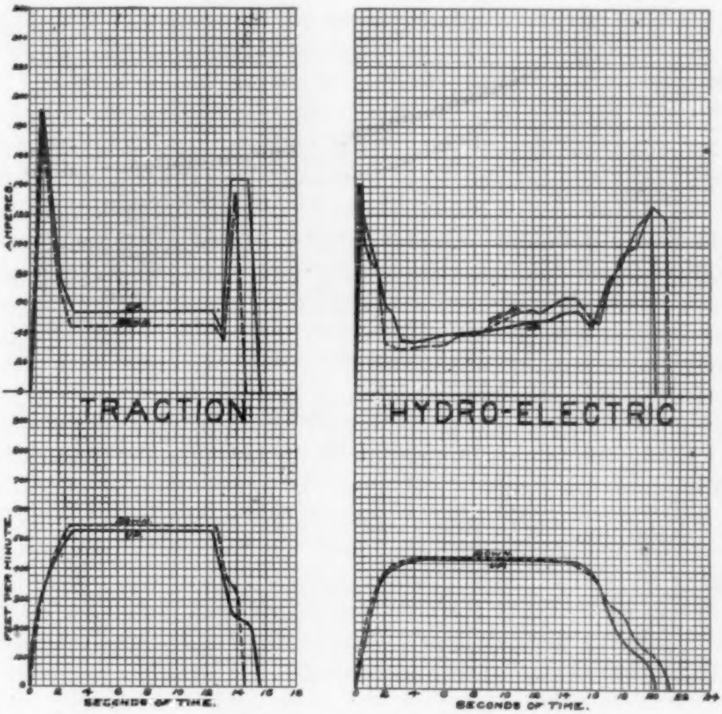


FIG. 2

brake. Two automatic valves are placed between the casing and water supply—one being automatically operated when the car reaches a point at a certain distance from the bottom floor and the other when the car arrives at a certain distance from the top floor.

7 We have at the Duane Street building a traction elevator which is run under similar conditions with the hydro-electric elevator, as this combination may be called. The travel of the car in both cases is about 120 feet, while the speed of the hydro-electric elevator is

approximately 450 feet per minute, and of the traction elevator approximately 550 feet per minute. We have made tests of both elevators under approximately equal conditions of service, and the slide shows curves of energy and speed covering both tests.

8 The curve of the hydro-electric elevator shows a large area for the braking current at the end of the run which is now being reduced by the application of other devices. The total current used per car mile in the case of the hydro-electric elevator under these conditions is 3.6 kilowatts per car mile; the current used for the traction elevator is 3.3 kilowatts per car mile. It should be noted that with better speed and higher lift these figures would undoubtedly be much reduced.

Mr. John D. Ihlder[1] The writer agrees with the author that the gearless one to one traction electric elevator, as it has been installed for the last years in several important buildings, is the best elevator so far designed for high buildings, but does not see how the addition of a control motor, working through a non-reversible worm gear could possibly be an improvement on the method of control that has been adopted. It would be difficult, if not impossible, to design a large slow speed motor, suitable for the duty of raising and lowering loads to synchronize with a small motor, designed to turn the worm gear only, in starting, stopping, and speed regulation. The large motor which does the duty must necessarily vary its speed to some extent with the duty performed. A small motor would necessarily have to be designed to run at the highest speed which the main motor is ever assumed to make. Under such a condition the control motor would tend to perform so much of the duty against the inefficient worm until its speed is reduced to the speed which the main motor has at any time. The useful work done by the control under these conditions with the inefficient worm would be small. On the other hand, if the control motor is designed to run at a slower speed than the maximum which the main motor can ever attain, the main motor will exert pressure against the worm which it is unable to run forward until it does sufficient work in friction to reduce its speed to the speed of the control motor. In both cases there is loss of energy and wear on the worm.

2 The perfect acceleration which is readily achieved through the control of the main motor only would be very difficult to accomplish if the control motor has to accelerate at the same rate. The present

[1] Engineer with the Otis Elevator Company, New York.

perfect method of operation, which is automatically accomplished to give quicker acceleration for light loads than for heavy loads, would require a very complicated auxiliary control apparatus if the control motor is to synchronize.

3 In practice it would probably be impossible to make such an apparatus. The result would be that the acceleration would be slower, and that during the acceleration either the main motor or the control motor would consume power, wasting it on the worm. If the control motor, while the elevator runs, should become short-circuited and stop short, some part of the apparatus would probably be wrecked making it a cause of danger instead of safety.

4 It has been customary to provide the one to one traction machine with a duplicate brake, or with a brake consisting of two duplicate halves, so that if one for any reason should fail, the other one is still there to perform its function. This takes care of all reasonable requirements for holding the car, especially if we consider that it is possible for an experienced operator to handle the car without a brake, and the application of the brake is made so gentle that it produces a perfect operation, when released as well as when applied.

5 The power consumed in running the small motor free is certainly more than the power required for the brake without considering the waste which must occur when the two motors do not synchronize together; also the space occupied by the small motor is considerably larger than the space occupied by the brake.

6 It would therefore appear that the addition of a control motor and inefficient worm gear is not a desirable feature, and it would require considerable experimenting to make it operative at all.

Mr. F. T. Ellithorpe[1] The introduction of elevators has stimulated inventors to patent a large number of safety devices. Some of these possess considerable merit, while many are practically worthless.

2 The accounts of elevator accidents from the published data which the speaker has gathered for many years is alarming, and a large majority of them are caused by the elevator operator not properly closing the elevator doors.

3 During the past year from this feature of elevator accidents the number ran up to about 750, this being a ratio of nearly 9 to 1, occurring from this direction, as against all other accidents happening from other causes on the vertical railroad.

[1] Engineer, New York.

4 Inventors have not given due attention to the providing of devices that properly safe guard elevator doors.

5 Would it not be wise to have a device that would act properly so as not to retard the speed of the elevator, and yet produce more protection to the passengers?

6 You are probably aware that there are several devices on the market which have not been entirely satisfactory; most of them seriously retard the speed of the elevator. What seems necessary is a device which will cause the operator to be more careful in the closing of the elevator doors. With this properly done, the accident lists in the future must be greatly decreased.

INDUSTRIAL EDUCATION

By W. B. Russell, Published in October Proceedings

Mr. H. L. Gantt We are much indebted to Mr. Russell for his admirable description of a system of industrial education which seems bound to produce good results.

2 The shop instructor is a most valuable man, whether the shop contains apprentices or not. The writer has been familiar with him for twenty years, and has not only often been one himself, but has spent a great part of his time during recent years training shop instructors. The shop instructors who have been most useful to the writer are not so often those that have the necessary tact, as explained by Mr. Russell, as those that have the necessary firmness. More good training can be gotten out of the every day work of a shop than out of any other school, but to make such training available, the orders must be given as tasks, and each task must be specific as to:

a What is to be done,
b How it is to be done, and
c The time allowed to do it.

3 A proper instructor sees that the recipient of the order understands exactly what is to be done and teaches him how to do it in the time set. Such a scheme of instruction involves a means for task setting and a means for inducing the workman to perform the task. The task should be set only after proper study by a capable man, and the method of performing it should, whenever possible, be written out, showing the important steps in their proper order with the time needed for each. Such descriptions or "instruction cards" are of great assistance to the instructor, and the more intelligent workmen readily learn to follow them.

4 So much for the task and the instructions. How to make the workmen perform the task is another question. In dull times when men are badly in need of work, it is often possible to make the performance of the task a condition of employment, or a piece price may be set.

5 If however the operation is one often repeated and one at which a workman may acquire skill and speed with repetition, the task should be so much greater than an ordinary man can do at once that he is apt under either of the above conditions to give up the job. On account of this condition of affairs the writer devised his system of paying every man a day rate, and to those who succeed in accomplishing the task, an additional amount, or *bonus*.

6 The success of this method of instructon has been most marked. The results have been:

a An increase of output,

b A reduction in cost,

c The development of highly skilled workmen, who in turn have yielded an unusually large crop of good foremen.

This bears out Mr. Basford's statement in his discussion of Mr. Jackson's paper that if we have a good organization as to rank and file, the captains and subordinate officers will not constitute a problem.

7 The scheme described by Mr. Russell, good and useful as it undoubtedly is, is applicable only to special cases and to rich and powerful corporations.

8 What the writer has described is in successful operation in one shop containing ten workmen, several between twenty and fifty, and others having a larger number. These shops represent four industries: wood, cotton, iron and steel.

COLLEGE AND APPRENTICE TRAINING

BY PROF. JOHN PRICE JACKSON, PUBLISHED IN OCTOBER PROCEEDINGS

H. L. GANTT Mr. Jackson's valuable paper has brought out much equally valuable discussion, and the writer feels with some of those that have already discussed it that a college education should not entitle a man to special consideration but should make him independent of it. In other words, if his college education is of any value to a man, he should on account of it be less dependent upon special privileges.

2 The greatest defects the writer has found in college graduates

are: their inability to carry out orders exactly, and their lack of knowledge of how to do a day's work. The writer has found that if he can teach them how to do exactly what is wanted, and how to do a big day's work, they can as a rule soon acquire the special knowledge needed to make themselves very useful.

3 Following this idea, the writer has adopted the practice of giving college graduates simple work of a routine character, but in such quantity as to keep them very busy all day, and has had most excellent results; those that stood the test almost always advancing rapidly.

4 When I was a boy I often heard an old gentleman whom I very much admired tell a story about Stephen Girard. It seems that some time in his career Stephen Girard kept a hardware store in Philadelphia, and on a certain occasion had a grind stone standing on the sidewalk. He hung out a sign "BOY WANTED." Soon a boy applied and was hired. He was told to go and turn the grindstone. The boy wanted to know what he was to turn the grindstone for, and was told that he need not worry about that, he would be paid for it. The boy went out, looked at the grindstone, and went down the street. Other boys were hired, some declined to turn the stone at all and others turned it for a few minutes and quit.

A few days later in reply to a comment made about a particularly efficient boy he had, Mr. Girard replied, "That boy turned the grindstone."

W. F. Hendry Referring to Mr. Porter's remarks on Professor Jackson's paper concerning "student courses" in various large manufacturing establishments I would state that the Western Electric Company has an educational department and the practice of hiring young men and putting them through a regular course of training has been followed by us for many years.

2 In the New York factory we have four broad types of student courses.

a A course to fit the student to hold executive positions in general.

b A course to provide men to fill such positions as assistant foremen, telephone engineers, shop office department heads, inspection department, etc.

c A course to provide men for executive positions in the office or clerical branches.

d A course for young men or boys who wish to learn a trade.

3 In addition to these there is the regular summer course for

college men who wish to put in not less than eight weeks of their vacation at practical work.

4 The first and most important is the four year contract course which is open to graduates of colleges or technical schools with a degree equivalent to B.S. In order to show that the training is by no means all electrical, I will give the curriculum.

Punch press department	4	weeks.
Drilling department	4	"
Screw machine department	12	"
Milling department	8	"
Pattern making department	4	"
Brass foundry	3	"
Shop store rooms	3	"
Shop order department	3	"
Nickel plating department	3	"
Tool room	38	"
Assembly department	12	"
Inspection department	8	"
Blacksmith department	4	"
Cabinet making department	4	"
Switchboard wiring department	12	"
Outside installation work	12	"
Drafting department	12	"
Shop cost department	4	"
	15	"

5 The student is put to work on a screw machine, drill press or milling machine, adjacent to and on precisely the same basis as the regular workmen, working on a day rate or piece work rate. Many cases are on record where the student has made as good wages as the regular workman. They are not however kept on any one job more than three or four days, the idea being to give them as many different operations as possible.

6 You will note that nearly a year is spent in the tool room. Before the student leaves this department he makes from raw material several jigs, punches, dies, etc., which must be perfectly commercial articles. Here he also obtains experience in the proper design of tools in the tool drafting branch of the tool room.

7 In order to insure thorough routine, the student fills out the regular time tickets which after having passed through the Pay Roll Department are sent to the head of the educational department who thus has a constant check on the men and knows just what they are doing.

8 The students all belong to the Western Electric club which meets in this building once a month, at these meetings papers are read and discussed. In addition to this, they receive a monthly talk or lecture by some department head on general manufacturing or engineering topics.

9 Among many others the following positions are held by graduates of the student courses of the New York factory:

Superintendent, Antwerp factory; Assistant head of design engine department, New York factory; Assistant manager, Tokio factory; Chief engineer, Berlin factory; Head output department, New York factory; Assistant head inspection department, New York factory; Manager, Antwerp factory; Master Mechanic, Tokio factory.